Spring 2006

The Winter Ecology of the Piping Plover (Charadrius melodus) in Coastal Georgia

Brandon Lennon Noel

THE WINTER ECOLOGY OF THE PIPING PLOVER (*CHARADRIUS MELODUS*) IN COASTAL GEORGIA

by

BRANDON LENNON NOEL

(Under the Direction of C. Ray Chandler)

ABSTRACT

The Piping Plover (*Charadrius melodus*) is a federally listed species with three distinct breeding populations, including Great Plains (threatened), Great Lakes (endangered), and Atlantic Coast (threatened), all of which winter along the Atlantic and Gulf coasts of the United States. I studied the winter ecology of Piping Plovers on Little St. Simons Island (LSSI), Georgia from 2003-2006, with emphasis on the conservation significance of this site for the endangered Great Lakes population. During 2003-2004 and 2004-2005, LSSI supported up to 100 Piping Plovers during peak migration, and approximately 40 birds wintered at this site. All populations had similar patterns of arrival, departure, and winter residence times on the island. Of the color-banded plovers observed on LSSI during 2003-2004, 35% were observed the following year; 69% of plovers that wintered in 2003-2004 returned to winter in 2004-2005. Wintering plovers show high site fidelity to particular beaches on LSSI within years. Foraging success of Piping Plovers was highest (35.3% of foraging maneuvers) on beaches adjacent to the Altamaha River at the north end of the island. This area also had a different sediment composition (more coarse silt and very fine sand) and greater prey abundance (*Nereis sp.*) than other parts of the island. My results suggest that LSSI is one of the most important wintering sites on the Atlantic coast for the Piping Plover, especially the endangered Great Lakes population. All breeding populations of Piping Plovers have similar patterns of temporal occurrence on LSSI, suggesting no need for population-specific management plans at this site. My data on site fidelity and foraging success suggest that relatively small areas on LSSI may be of disproportionate importance to wintering Piping Plovers. Critical habitat designations should take account of this within-island variation.

INDEX WORDS: Piping Plover, *Charadrius melodus*, Winter Ecology, Migration, Residence Time, Site Fidelity, Foraging Success, Prey Abundance, Sediment Composition, Georgia, Atlantic Coast

THE WINTER ECOLOGY OF THE PIPING PLOVER (*CHARADRIUS MELODUS*) IN COASTAL GEORGIA

by

BRANDON LENNON NOEL

B.S., University of West Florida, 2000

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

STATESBORO, GEORGIA

2006

THE WINTER ECOLOGY OF THE PIPING PLOVER (*CHARADRIUS MELODUS*) IN COASTAL GEORGIA

by

BRANDON LENNON NOEL

Major Professor: C. Ray Chandler

Committee: Daniel Gleason
Lissa Leege

Electronic Version Approved:

May 2006

DEDICATION

I dedicate this work to those who have aspired to preserve and conserve the natural world in the face of disturbance, eradication, or disregard. The human race has incessantly tarnished species richness throughout the planet and spoiled the world's richest ecosystems. However, since the beginning of civilizations, there have been individuals who have recognized the beauty and balance our planet possesses. I dedicate this thesis to those individuals and researchers who came before me, are with me now, and will follow me. These people have inspired me to make a difference in the world for imperiled species and ecosystems. The Piping Plover is one representative species of many that symbolizes the impacts of human's egocentricity and apathy concerning his and her surrounding environments. It is my ambition that we can help enlighten humanity to the necessity in the world we continue to annihilate. Regardless of whether most choose to accept it or not, we coexist in a balance with our environment, and the human race will not persist if we continue to demolish the ecosystems and slaughter the inhabitants of those ecosystems. There can be an equilibrium established between wildlife and development (our current sustained existence), and my life is dedicated to making every effort possible to generate a difference for otherwise defenseless species to human's greed.

ACKNOWLEDGMENTS

I express my deepest appreciation to Dr. C. Ray Chandler for all of his assistance and guidance throughout this project and for granting me this special opportunity. I thank him for all of his patience and support throughout the statistical analyses, editing, and the camaraderie in which he gave ever so freely. I can not thank Brad Winn enough for all of his logistical assistance, field efforts, grant acquisition assistance, and guiding support prior, during, and after this study. My committee members, Drs. Daniel Gleason and Lissa Leege gave their crucial advice and support throughout my study and writing. Thank you very much to both of you!

Sincerest thanks to Patrick and Doris Leary for their photos of color-banded individuals and their ongoing conservation efforts in Florida. I thank all those who assisted me in the field, including Bill Mueller, Brad Winn, Brian Harrington, Clay George, Joelle Gehring, Amy Logan, Bridget Olson, Natasha Atkins, Alex Wilke, Robin Hunnewell, Stephen Brown, Nathan Farnau, Leigh Youngner, Duane Noel, Carole Noel, Andrew Grosse, Grace Greenwood, and Catherine Arning. Jennifer Stucker, Francesca Cuthbert, Jack Dingledine, Cheri Gratto-Trevor, Sharilyn Westworth, Diane Amirault, Julie McKnight, Jonathan Cohen, and Rosemary Vander Lee provided all information and confirmation on color-banded individuals from each of the three breeding populations.

I thank Hank and Wendy Paulson, Anne Hecht, Patty Kelly, Terry Moore, C. Ray Chandler, Brad Winn, Daniel Gleason, and Lissa Leege for providing support and critical advice for grant acquisition. This research was funded primarily by Leica Sports Optics, The Bobolink Foundation, and the United States Fish and Wildlife Service, Panama City

Office. Other funding was generously provided by the Georgia Ornithological Society's H. Branch Howe, Jr. Research Grant, The Environmental Resources Network (T.E.R.N.) "Friends" of Georgia's Nongame & Endangered Wildlife Program, Jon and Michelle Gillett, Georgia Southern University's Graduate Student Professional Development Fund, Eastern Bird Banding Association, and the American Ornithologist Union's Marcia Brady-Tucker Travel Award. Brad Winn and the Georgia Department of Natural Resources provided an ATV for three months during the first year of the study due to my inability to walk (leg injury).

I thank Jeremy Camp for his hard work in the lab processing sediment and prey samples, and Dr. Eleanor Camann for her enhanced expertise on sediment. Dr. James Reichard, Dr. Fredrick Rich, Dr. James Darrell, Dr. Richard Snyder, Dr. Philip Darby, Dr. Wayne Bennett, Dr. Bill Savidge, Dr. Dionne Hoskins, Dr. Clark Alexander, and Jeannie Butler offered advice and assistance concerning sediment and prey samples. I thank Dr. Joelle Gehring for her assistance with home-range programs.

Of course, special appreciation is extended to my family, who has stood by me and been my number one supporters throughout. I could not have done it without the love and support I received from my cat, Naomi, my mother, Carole Noel, my father, Raymond Noel, my brother, Duane Noel, my grandmother, Ann Noel, and my stepmother, Diane Noel. A final and special thank you to the owners and staff of the Lodge on Little St. Simons Island for access to the study site, logistical support, and the use of their equipment (gasoline, truck transportation, bicycles, canoes, etc.) during the study, and for their continued commitment to the conservation of this precious island for nearly 100 years.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Shorebirds, birds of the families Scolopacidae and Charadriidae, are well-known for their spectacular migrations. These migrations, often traversing continents and covering thousands of kilometers, enable shorebirds to exploit the environment at a global scale. The principal advantage is that shorebirds can move between ephemerally favorable habitats despite great distances. A key disadvantage, particularly in light of human population growth, is that many species of shorebirds depend on relatively small, vulnerable wetlands as key stopover or wintering sites. At least 21% of the world's shorebirds (32 of 155 species) are listed as species of conservation concern by Birdlife International (Piersma et al. 1997), and wintering populations of shorebirds throughout North America are declining (Morrison et al. 2001). In particular, Red Knots (*Calidris canutus*) are declining at alarming rates (Baker et al. 2004, Morrison et al. 2004). Development or conversion of relatively small sites can have a disproportionate impact on the populations of many shorebirds (Myers et al. 1987, Howe et al. 1989, Pfister et al. 1992, Hitchcock and Gratto-Trevor 1996, Warnock et al. 1998, Withers 2002, Warnock et al. 2004)

The Piping Plover (*Charadrius melodus*) is another example of the sorts of threats that shorebirds face (Haig et al. 2005). This species is a small, stocky, sandy-colored shorebird approximately 18 cm in length with a wingspan of 38 cm and a mass ranging from 43 - 63 g. In the United States, the Piping Plover is a federally listed species with allopatric breeding populations in the Great Lakes region, the northern Great Plains, and along the Atlantic Coast (U.S. Fish and Wildlife Service 1996; Fig. 1.1). Populations on the Atlantic Coast and Northern Great Plains are federally listed as threatened (ca. 3000 birds each), and the Great Lakes population (ca. 200 birds) is endangered (U.S. Fish and Wildlife Service 1985). Originally listed as threatened in 1978, all birds breeding in Canada were listed as endangered by the Committee on the Status of Endangered Wildlife in 1985 (Haig 1985). The Canadian Wildlife Service and the U.S. Fish and Wildlife Service have produced cooperative recovery plans, primarily for breeding populations of this species, yet Piping Plover populations continue to decline on both the breeding grounds and wintering grounds according to the recovery plans established.

All populations of Piping Plovers are migratory and winter primarily in the southeastern U.S. (Fig. 1.1). Individuals from the Great Lakes depart their breeding grounds from mid-July to early September (Wemmer 1999); plovers from the Canadian prairies (Northern Great Plains population) generally depart their breeding grounds by the end of the first week in August (Whyte 1985, Wershler and Wallace 1986). The migration of Piping Plovers is poorly understood (U.S. Fish and Wildlife Service 2001), but few birds are seen at inland sites during migration, so most birds probably migrate non-stop from their breeding grounds to their wintering grounds (Haig 1992). Piping Plovers begin arriving on the wintering grounds in July. All Piping Plovers, regardless of population, are considered a threatened species when on their wintering grounds (U.S. Fish and Wildlife Service 2001).

Despite protection from the Migratory Bird Treaty Act of 1918, development and recreational use of beaches and shorelines are contributing to ongoing declines of Piping Plover populations (Haig and Oring 1985). Oil spills, dredging, construction of sea walls and jetties that affect natural beach dynamics, expansion of inter-coastal waterways, beach restoration, and dune stabilization also have impacted Piping Plover populations (Nicholls and Baldassarre 1990b, Haig and Plissner 1992, U.S. Fish and Wildlife Service 1994). The decline in Piping Plovers has prompted dozens of studies, including extensive color-banding, focused on breeding ecology and reproductive success (Cairns 1977, Haig and Oring 1985). In fact, virtually all the conservation-related research on this species has focused on the breeding grounds, although Piping Plovers spend only 3-4 months out of the year there. This is unfortunate because events on the wintering grounds are probably a critical component of this species' life history (Baker and Baker 1973). The paucity of information on wintering populations limits the ability to identify precisely the causes of the present population decline (Johnson 1987). Furthermore, increasing development and recreational beach use along the coasts of the southern U.S. makes the collection of data on the winter distribution and ecology of the Piping Plover a high priority (Plissner and Haig 1997).

A rare survey of wintering plovers on the Atlantic coast (Nicholls and Baldassarre 1990a) found that Georgia had the highest number, frequency, and density per km surveyed of wintering Piping Plovers. Nicholls and Baldassare (1990a) also found that Little St. Simons Island, Glynn County, Georgia, had the largest concentration on the Atlantic coast. During the 2001 international wintering census, Georgia had the highest number of Great Lakes plovers color-banded the previous summer of the coastal states surveyed (Ferland and Haig 2002). Furthermore, although Piping Plover numbers declined 27% between the 1991 and 1996 international censuses, the number of wintering Piping Plovers reported in Georgia increased (Plissner and Haig 2000). These data suggest that the barrier islands of Georgia may be important wintering area for these threatened plovers. In fact, the U.S. Fish and Wildlife Service (2001) designated Little St. Simons Island and other barrier Islands in Georgia as 16 of the 142 areas along the south Atlantic coast and Gulf coast that provide critical habitat for wintering Piping Plovers.

Unfortunately, there have been no studies on the winter distribution, migration habits, site fidelity, or habitat use of the three separate breeding populations of Piping Plovers in this important region. Furthermore, development of an effective recovery plan for the three breeding populations of Piping Plovers is hindered by the lack of knowledge about their winter distribution and winter habitat use along the Atlantic coast (Plissner and Haig 1997). Thus, the objective of my study is to address four important hypotheses concerning the winter ecology of Piping Plovers in coastal Georgia:

(1) *Little St. Simons Island is one of the most important sites for Piping Plovers along the Atlantic coast.* Based on the few available surveys, I predict that Little St. Simons Island will support larger numbers of Piping Plovers during winter and migration than any other site previously censused on the Atlantic coast. I further predict that Little St. Simons Island will support more Great Lakes individuals than any other site on the Atlantic coast.

(2) *Piping Plovers can be managed on Little St. Simons Island without need for population-specific criteria.* I predict that Piping Plovers from the three populations will arrive, reside, and depart at the same time.

(3) *Piping Plovers will show high site fidelity on Little St. Simons Island because of high habitat quality.* I predict high between-year faithfulness and within-year

faithfulness to beaches on Little St. Simons Island. I further predict high detectability and small home range sizes for wintering plovers present on Little St. Simons Island.

(4) *Piping Plovers are selective in their use of Little St. Simons Island beaches.* I predict that Piping Plover abundance will vary among beaches on Little St. Simons Island. I further predict that foraging success will vary within beaches and this variability will correlate with prey abundance and sediment composition.

By testing these four hypotheses, I will provide the most detailed population census available for Piping Plovers at any single wintering site. I will also relate the spatial distribution and site faithfulness of Piping Plovers to habitat features that may help explain the distribution of Piping Plovers. These data should help managers produce more precise management and recovery plans for this declining species (Plissner and Haig 1997).

STUDY AREA

This study was conducted on Little St. Simons Island (Fig. 1.2), Glynn County, Georgia (ca. 31° 26' N, 81° 27' W). Little St. Simons Island (LSSI) is a 5260-ha privately owned, undeveloped barrier island located at the southern branch of the Altamaha River Delta. The Altamaha River is the second largest river basin in the southeastern United States, and it deposits large volumes of sediment along LSSI's north end. Thus, LSSI is characterized by expansive tidal flats. The Western Hemisphere Shorebird Reserve Network (WHSRN) designated LSSI and the surrounding delta system as the 42^{nd} International Shorebird Reserve Site. In addition, the National Audubon Society and American Bird Conservancy named this site as one of the top 500 Important Bird Areas in the country. The United States Fish and Wildlife Service designated LSSI as critical wintering habitat for Piping Plovers (GA-13, United States Fish and Wildlife Service 2001).

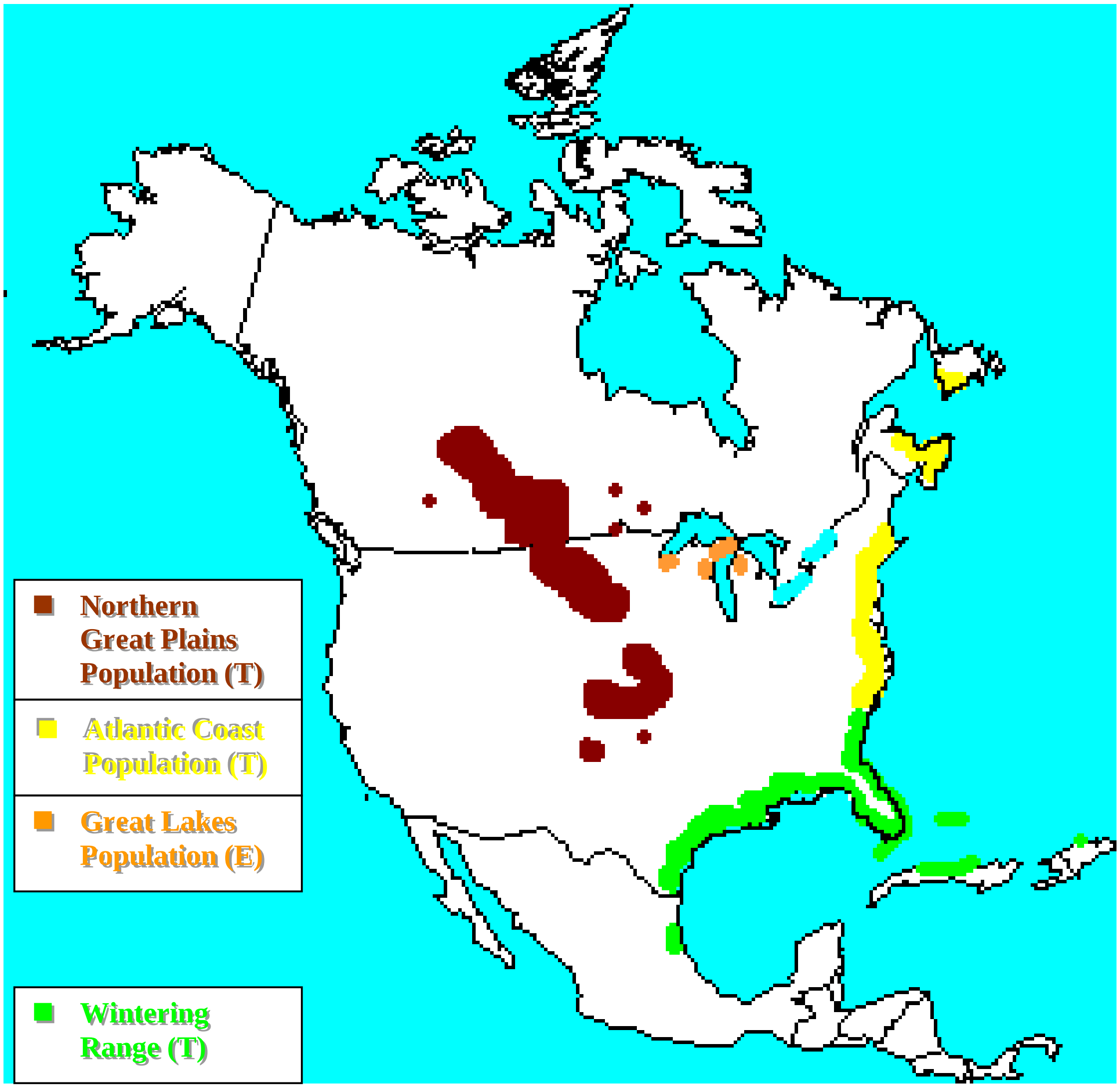


Figure 1.1 Piping Plover breeding and wintering range. The Atlantic Coast and Northern Great Plains populations are threatened totaling ca. 6000 plovers. The Great Lakes population is endangered totaling ca. 200 plovers. All plovers are threatened on the wintering range (Haig 1985).

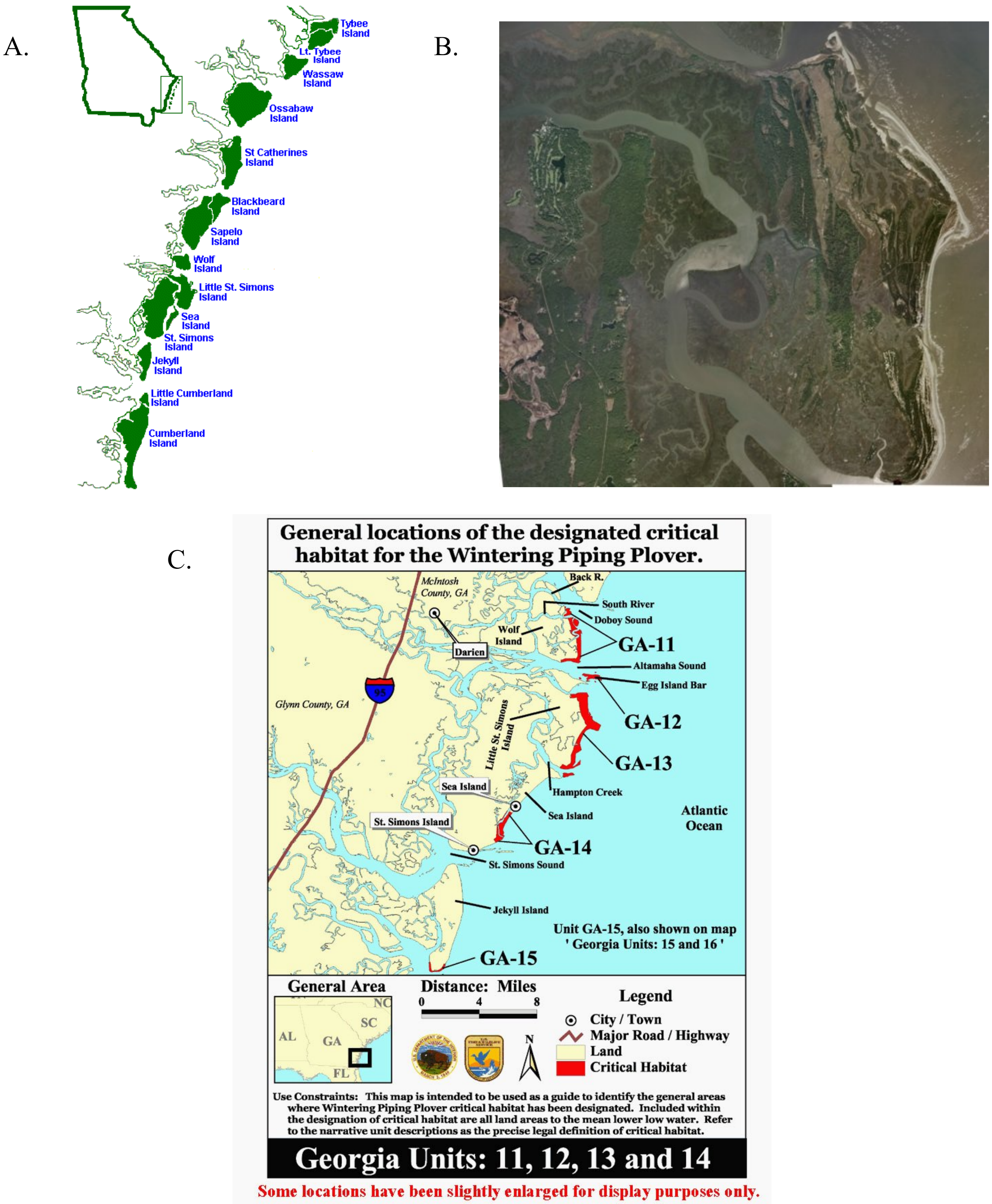


Figure 1.2 Piping Plover study area during the 2003-2004, 2004-2005, and 2005-2006 study years. Location of Little St. Simons Island (LSSI) along the Georgia coast (A), aerial image of LSSI showing beaches to the right and the Altamaha River Delta along the top (B), and the critical wintering habitat designations, including LSSI as GA-13, and Egg Island Bar as GA-12 (United States Fish and Wildlife Service 2001).

CHAPTER II

ABUNDANCE AND SEASONAL MOVEMENTS OF PIPING PLOVERS ON LITTLE ST. SIMONS ISLAND, GEORGIA

INTRODUCTION

One of the principal challenges of managing shorebird populations is to obtain accurate census data from widely separated and often remote breeding, stopover, and wintering sites. Even at well-studied sites such as Copper River Delta or Delaware Bay, accurate estimates of shorebird populations have been a challenge to obtain. Color marking can help with the tracking of populations (e.g. Red Knot, Dunlin, Western Sandpiper, Semipalmated Sandpipers; Harrington et al. 1988, Ruiz et al. 1989, Butler et al. 1996, Hitchcock and Gratto-Trevor 1996,), but reports regarding color-banded shorebirds are usually limited to a minimal number of locations and dates.

The Piping Plover is a good example of these challenges. Although breeding populations are well-studied, including extensive color-banding around the Great Lakes, their winter distribution is less clear. Winter censuses in 1991, 1996, and 2001, located only 63%, 42%, and 40% of the estimated breeding numbers of Piping Plovers on their wintering grounds (Ferland and Haig 2002). These findings suggest that wintering plover habitats remain unidentified, or a number of plovers remain undetected at wintering sites during annual surveys. In addition, little is known about the patterns of arrival, departure, and winter movements of Piping Plovers, especially for individuals from known breeding populations. With increasing coastal development and recreational beach use within its wintering range, it is imperative that we gain a better understanding of the distribution and seasonal movements of nonbreeding Piping Plover (Plissner and Haig 1997).

Nicholls and Baldassarre (1990a) found Georgia to have the highest numbers of Piping Plovers on the Atlantic coast during winter. Three sites in Georgia; Little St. Simons Island, Cumberland Island, and Pelican Spit; had more Piping Plovers than all other sites surveyed on the Atlantic coast (Nicholls and Baldassarre 1990a). In 2001, the U.S. Fish and Wildlife Service (2001) designated Little St. Simons Island (including Pelican Spit) and Cumberland Island as two of sixteen areas along the Georgia coast that provide critical habitat for wintering Piping Plovers. Therefore, Little St. Simons Island (LSSI) is an ideal spot to acquire an improved understanding of Piping Plover abundance and seasonal movements.

A further advantage of LSSI is the previously documented presence of color-banded Piping Plovers (B. Winn, Georgia Department of Natural Resources, unpublished data). Of the three breeding populations, the Great Lakes population is listed as endangered, whereas the other two are classified as threatened (U.S. Fish and Wildlife Service 1985). According to a 2004 survey, the Great Lakes population was composed of approximately 200 birds (55 breeding pairs and 90 surviving fledglings); 90% of all Great Lakes plovers were color-banded (J. Stucker, University of Minnesota, pers. comm.). The Great Plains and Atlantic Coast populations' total approximately 3000 individuals each, but proportionally fewer are color-banded (approximately 300 from the Great Plains and approximately 115 from the Atlantic Coast).

As described in Chapter 1, I hypothesize that LSSI is one of the most important wintering sites for Piping Plovers along the Atlantic coast. I predict that LSSI will have more Piping Plovers and more Great Lakes plovers than other sites previously censused. I further hypothesize that management plans for LSSI will not need to be population-specific. I predict that arrival, residence times, and departure will be the same for all populations. Prior to this study, there had been no comprehensive study of Piping Plover abundance and seasonal movements at one wintering site on the Atlantic coast.

METHODS

I collected data over two consecutive study years, 2003-2004 and 2004-2005. Each study year began upon arrival of the first Piping Plovers in July and ended upon departure of the last plover in May.

I quantified abundance of migrating and wintering plovers monthly by conducting beach surveys every 6 to 7 days. The mean time between surveys was 4.7 days; only 6/132 surveys was the interval greater than 10 days. During half of the weeks (67/132 surveys; 50.8%), I surveyed the entire 11 km of beach on LSSI by foot, bike, or ATV. Most of the surveys not completed (55/65; 84.6%) excluded only the southern portion (4.5 km) of the island - an area of low plover density (see results). I conducted surveys primarily at low tide (defined as the period from 2 h after high tide until 2 h before the next high tide) to maximize observability of plovers. However, for comparison I surveyed at high tide a minimum of once per month. I surveyed at a sufficiently rapid pace (mean = 3.13 hours/survey, n = 132 surveys) to minimize the chance that plovers moved to new parts of the beach during the surveys and were double counted. Color-banded individuals were seen twice during a survey only 10 times.

I used binoculars (Leica 8 x 10) and spotting scope (Leica Televid 20x - 60x) to record color-band combinations that identified individuals from the three breeding populations, and I recorded the number of plovers that did not have color-bands. Based on color-band combinations and date of sightings, I estimated median arrival date (first sighting), median departure date (last sighting), and residence times (number of days from arrival to departure) for individuals from known breeding populations. I defined color-banded individuals as migrants if they were not observed on the island between November and February; individuals present between November and February were defined as wintering individuals. The population from which color-banded plovers originated was confirmed by reporting sightings to the original banders on the breeding grounds (pers. comm. J. Stucker, University of Minnesota, D. Amirault, C. Gratto-Trevor, and J. McKnight, Canada Wildlife Service). Because of the thoroughness of the surveys, color-banded plovers that were not observed for 4 weeks were assumed to be absent from the island. I summarized survey data as mean number of plovers detected per survey per month. In addition to surveys on LSS, I opportunistically surveyed Egg Island Bar (Fig. 1.2) twice in 2005. These surveys were not included in calculations of overall Piping Plover abundance, but they were included in estimates of Great Lakes plover abundance.

I could not directly assess survival. However, I indirectly measured survival by defining a color-banded plover as a winter mortality if three conditions were met. First, the individual had to be confirmed to be wintering on LSSI (multiple sightings November through February). Second, the individual had to disappear from LSSI during the winter months. Finally, the individual had be unreported on the breeding grounds subsequently.

All arrival and departure dates from each study year were converted to Julian dates for statistical analyses using JMP 3.0.2 (1994). Because these data were not normally distributed, I used the Kruskal-Wallis test to compare arrival and departure times among populations. Residence time data were normally distributed, and I used a

Model I ANOVA for 2003-2004, testing for differences in residence times among breeding populations. During 2004-2005, there were no individually recognizable plovers from the Great Plains or Atlantic Coast population to test for differences in residence times.

RESULTS

Overall abundance

All birds - Piping Plovers occurred on LSSI from July - May, with maximum numbers during fall migration (Fig. 2.1). Averaged over both study years, there were 7.9 Piping Plovers/km of beach surveyed during the height of fall migration (September). The maximum number of plovers detected during one survey was 109 on 19 Sep 2003 and 126 on 3 Oct 2004. During 2003-2004, approximately 45 Piping Plovers (4.1/km of beach) wintered on LSSI (Fig 2.1). In 2004-2005, winter numbers declined from 54 (4.9/km of beach) to 23 (2.1/km of beach) over the course of the season (Fig. 2.1).

Color-banded Piping Plovers - At any given time, approximately 20 - 30% of Piping Plovers on LSSI were color-banded; a minimum of 86 color-banded plovers (see Appendix A) occurred on LSSI throughout the study. Of these 86, 60 individuals were from the Great Lakes population, 10 from the Great Plains, and 16 from the Atlantic coast (Fig 2.2).

Sufficient numbers of Great Lakes birds were color-banded to allow more detailed assessment of their abundance. Averaged over both study years, there was 2.4 Great Lakes plovers/km of beach during the height of migration (September; Table 2.1). The maximum number of Great Lakes birds detected during one survey was 14 on 19 Sep 2003 and 19 on 3 Oct 2004. In 2003-2004, 15 Great Lakes Piping Plovers (1.4/km of beach) wintered on LSSI (Table 2.2). In 2004-2005, winter numbers declined from 15 (1.4/km of beach) to 9 (0.8/km of beach) over the course of the season (Table 2.3).

I visited Egg Island Bar (Fig 1.1) in March and April 2005 (Table 2.1). I saw four Great Lakes plovers, three of which occurred on LSSI.

Winter Mortality

I defined two birds (both from the Great Lakes) as winter mortalities in 2003-2004 (Table 2.2). During 2004-2005, there were nine winter mortalities, including six Great Lakes individuals, two Great Plains individuals, and one individual believed to be from the Atlantic Coast (Table 2.3). Six of these nine individuals wintered on LSSI both study years.

Population-specific Movements

Great Lakes individuals arrived significantly earlier than the other two populations ($H = 8.59$, $df = 2$, $p = 0.01$) in 2003, but not in 2004 ($H = 3.62$, $df = 2$, $p = 0.16$)(Table 2.4). All three populations had similar departure dates during 2003-2004 ($H = 2.82$, $df = 2$, $p = 0.24$) and 2004-2005 ($H = 2.04$, $df = 2$, $p = 0.36$). The mean residence time for all individually marked plovers that wintered and were not defined as winter mortalities was 230.6 ± 5.3 days in 2003-2004 (Table 2.2), and 275.7 ± 3.8 days in 2004-2005 (Table 2.3). Great Lakes individuals did not reside significantly longer than the other two populations during the 2003-2004 study year ($F = 2.97$, $df = 2, 13$, $p = 0.09$). Mean residence times were 237.1 ± 5.9 days for Great Lakes, 219.7 ± 4.5 for Great Plains, and 199 for the one Atlantic Coast individual. No Great Plains or Atlantic Coast for comparison in 2004-2005.

DISCUSSION

Accurate census data are one of the most important requirements for informed management of shorebird populations (Clark et al. 1993, Warnock et al. 1998, Plissner and Haig 2000, Haig et al. 2005). My results provide the most detailed surveys of the abundance of threatened and endangered Piping Plovers wintering at any one site on the Atlantic coast. These data permit three important conclusions about Piping Plover winter abundance in coastal Georgia.

First, LSSI supports one of the largest concentrations of Piping Plovers on the Atlantic coast. This is especially true given the island's relatively small size. I observed more Piping Plovers overall and per km of beach than reported for other wintering sites on the Atlantic coast (Nicholls and Baldassarre 1990a, Dinsmore et al. 1998, Dodd et al. 1999, Ferland and Haig 2002) or in Georgia specifically (Table 2.5). This suggests that the designation of LSSI as critical habitat is fully justified. However, LSSI is only part of the larger Altamaha delta (Fig 1.1). My data demonstrate that some plovers move from LSSI to other sites in the delta (Egg Island Bar), while others apparently do not cross from Egg Island Bar to LSSI. Detailed censusing of other parts of the delta should be a high priority, but the logistics will be a challenge (boat access only to multiple islands and bars). Even LSSI is closed to routine access. In comparing my data to other sites, it should also be noted that I surveyed on a weekly basis, whereas many other sites are surveyed for only a few hours or days (Nicholls and Baldassarre 1990a, Dinsmore et al. 1998, Dodd et al. 1999, Ferland and Haig 2002). More detailed censusing work may reveal larger numbers of Piping Plovers in other sites (see Chapter 3 for detectability of individual plovers).

Second, to the best of my knowledge, LSSI supports the greatest known concentration of Great Lakes Piping Plovers on the Atlantic and Gulf coast. According to a 2004 breeding survey, the Great Lakes population was composed of approximately 200 plovers, with 90% color-banded (J. Stucker, University of Minnesota, pers. comm.). During 2004-2005, I observed 40 Great Lakes individuals - a significant percentage (ca. 20%) of the entire breeding population - on LSSI. Furthermore, over my entire study, a minimum of 60 individuals from the Great Lakes population were seen on LSSI, which is consistent with the findings from the international winter census of 2001 that Georgia supported the highest concentration of Great Lakes plovers detected (Ferland and Haig 2002). No other study has reported abundances for wintering Great Lakes plovers of this magnitude. Piping Plovers from other breeding populations occurred on LSSI, but a much smaller proportion of these populations are marked. Thus, it is difficult to compare relative abundance of the three breeding populations on LSSI. Although there are some debates surrounding the color-banding of Piping Plovers (Amirault et al. 2006), such marking could contribute to comparative studies of winter ecology on sites such as LSSI.

Third, I found little indication of population differences in seasonal patterns of occurrence of Piping Plovers on Little St. Simons Island. All populations of Piping Plovers arrive on LSSI in July, reside on the island for almost 8 months, and depart in April (Tables 2.2 and 2.3). Piping Plovers are only absent from LSSI (and probably other Georgia beaches) during the month of June. The similarity in seasonal movements has management significance. If the endangered Great Lakes population occurred on LSSI on a significantly different schedule than other populations, future management plans might have to be complicated with population-specific schedules for regulations or management activity. Such similarity in migration schedules among populations of shorebirds is not always the case (Myers 1981, O'Reilly and Wingfield 1995, Warnock et al. 2004).

Finally, my results indicate considerable between-year variation in estimated mortality of marked, wintering plovers. This variation raises the important question of whether these mortalities can be associated with particular sites or habitats within the island. More generally, a better understanding of critical habitat needs on the wintering grounds requires data on the movements and site fidelity of Piping Plovers within LSSI. I address this need, and discuss winter mortality in more detail, in Chapter 3.

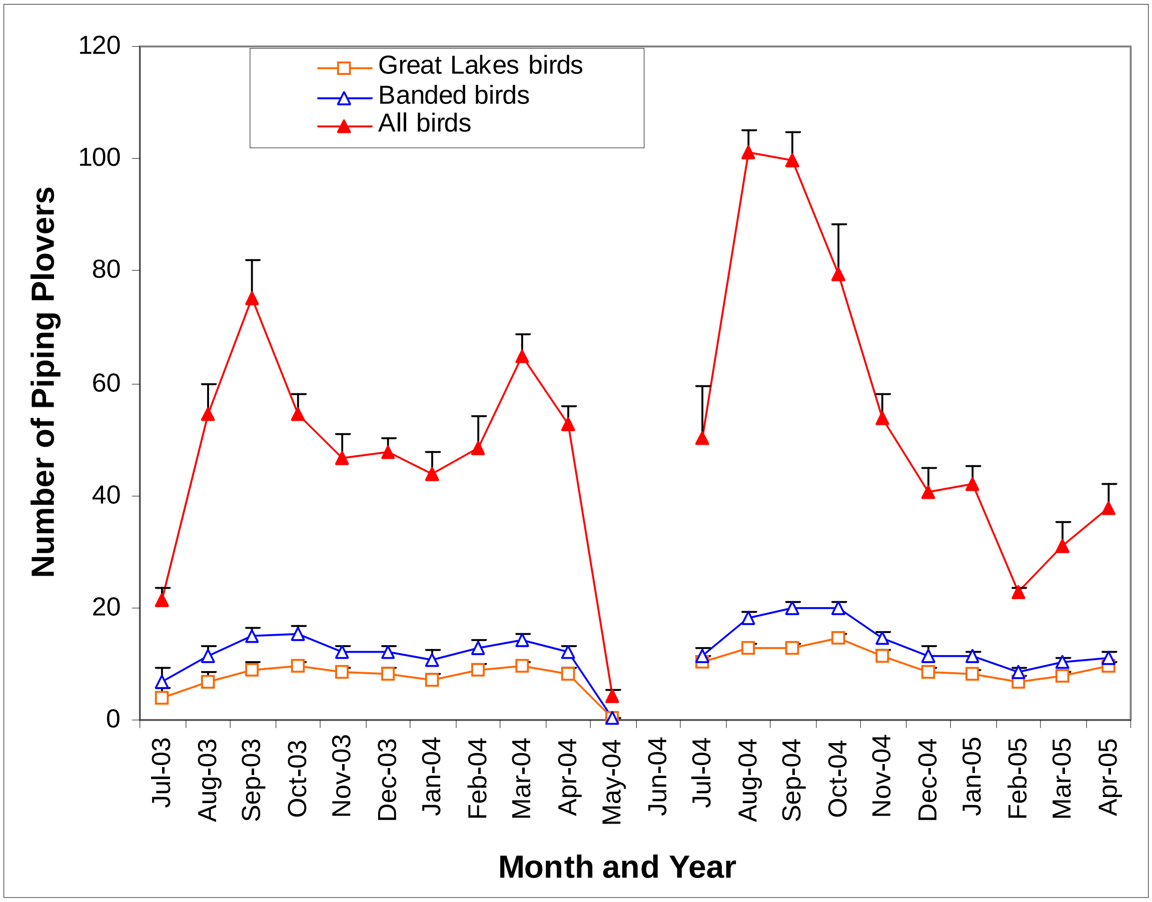
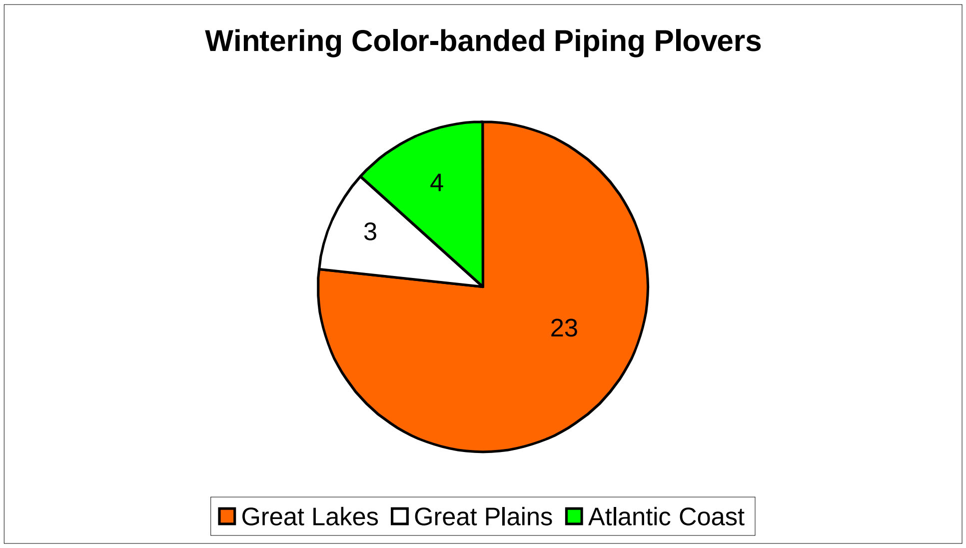


Figure 2.1 Number of Piping Plovers (mean ± SE) per month on Little St. Simons Island from July 2003 to May 2005 (n = 4 to 9 surveys/month). All means and standard errors are listed in Appendix B.



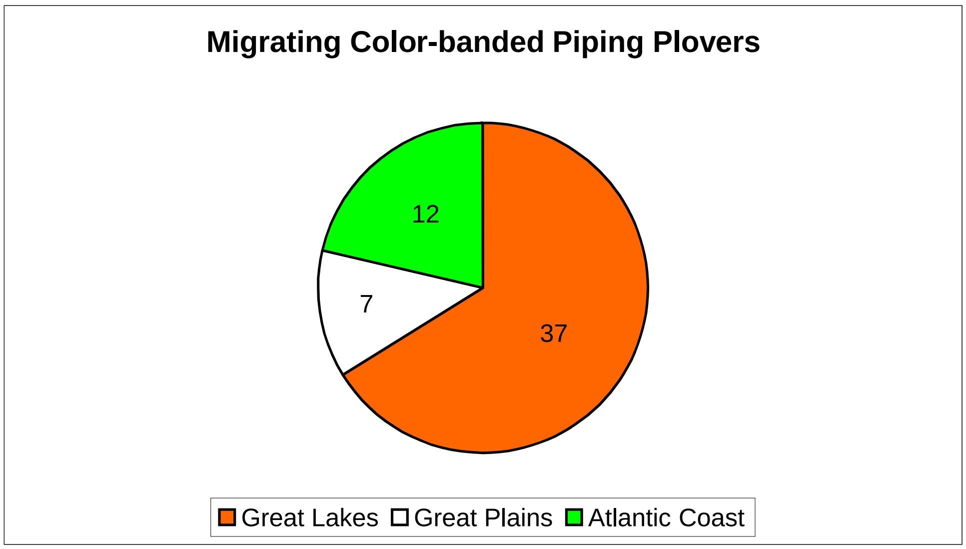


Figure 2.2 Number of color-banded Piping Plovers from each breeding population confirmed to winter on or migrate through Little St. Simons Island in the 2003-2004 and 2004-2005 study years. See Table 2.1 for more information on annual presence during wintering and migration.

Table 2.1 Total number of color-banded Piping Plovers from each breeding population documented each month during the 2003-2004 and the 2004-2005 study years on Little St. Simons Island.

	Surveys (n)	Great Lakes	Great Plains	Atlantic Coast		Surveys (n)	Great Lakes	Great Plains	Atlantic Coast
Jul 2003	6	8	0	2	Jul 2003	9	21	1	3
Aug 2003	4	16	3	6	Aug 2003	8	27	6	7
Sep 2003	6	27	7	6	Sep 2003	7	26	4	6
Oct 2003	6	17	3	9	Oct 2003	7	23	4	7
Nov 2003	5	17	3	4	Nov 2003	6	18	2	5
Dec 2003	6	14	3	3	Dec 2003	4	12	2	3
Jan 2004	5	14	3	2	Jan 2004	6	14	0	3
Feb 2004	5	14	3	3	Feb 2004	5	11	0	2
Mar 2004	8	16	3	6	Mar 2004	6	14 [a]	0	4
Apr 2004	7	17	4	5	Apr 2004	7	15 [a]	0	3
TOTAL	58	31	8	12	TOTAL	65	40	6	11
Migration [b]	37	16	5	9	Migration [b]	44	25	4	8
Winter [c]	21	15	3	3	Winter [c]	21	15	2	3

[a] includes one individual documented on Egg Island Bar that was not documented on LSSI
[b] includes July to October and March to April
[c] includes November to February

Table 2.2 Individually recognizable wintering Piping Plovers residence times from different breeding populations during 2003-2004 on Little St. Simons Island.

Band combination [a]	Breeding Population	Arrival (First sighting)	Departure (Last sighting)	Residence Time (days)
YO-GX	Great Lakes	21 Jul 2003	14 Apr 2004	269
LO-GX	Great Lakes	29 Jul 2003	7 Apr 2004	254
OX-BY	Great Lakes	29 Jul 2003	7 Apr 2004	254
LX-LO	Great Lakes	19 Sep 2003	20 Apr 2004	215
b-YO	Great Lakes	12 Sep 2003	20 Apr 2004	222
b , -	Great Lakes	3 Aug 2003	20 Apr 2004	262
OO-LX	Great Lakes	26 Jan 2004	20 Apr 2004	86 [b]
OL-BX	Great Lakes	4 Sep 2003	14 Apr 2004	224
OX-BO	Great Lakes	19 Sep 2003	28 Jan 2004	132 [c]
LO, -	Great Lakes	7 Sep 2003	24 Apr 2004	231
O/B, -	Great Lakes	3 Aug 2003	6 Apr 2004	248
- , O/Y	Great Lakes	3 Aug 2003	3 Mar 2004	214 [c]
- , OX	Great Lakes	28 Aug 2003	24 Apr 2004	240
- , YX	Great Lakes	3 Aug 2003	20 Apr 2004	237.5 [d]
- , LX	Great Lakes	4 Sep 2003	3 May 2004	220 [e]
mGG-FwO	Great Plains	19 Sep 2003	16 Apr 2004	211
mg-FwOR	Great Plains	12 Sep 2003	24 Apr 2004	226
mB-FwBG	Great Plains	12 Sep 2003	20 Apr 2004	222
X-RL ("A/B")	Atlantic Coast	19 Sep 2003	4 Apr 2004	199
- , X	Atlantic Coast	8 Aug 2003	28 Mar 2004	231 [f]
X, -	Atlantic Coast	27 Jul 2003	24 Apr 2004	247.5 [g]

[a] read left leg to right leg, separated by comma. Letters indicate color bands (L = black, X = metal, O = orange), lower case means light colored (b = light blue, but m = metal above tarsus), colored flag represented by Fw (white flag). Split band indicated by /

[b] individual wintered on southern portion of study area, which access was limited

[c] individual defined to be a winter mortality (residence time until death)

[d] two individuals with same band combination, but one individual migrated through LSSI and another wintered, so residence times +/- 23.5 days

[e] two individuals with same band combination, but one individual migrated through LSSI and another wintered, so residence time +/- 22 days

[f] two individuals with same band combination, but one individual migrated through LSSI and another wintered, so residence times +/- 3 days

[g] three individuals with same band combination, but two individuals migrated through LSSI and one wintered, so residence time +/- 25.5 days

Table 2.3 Individually recognizable wintering Piping Plovers residence times from different breeding populations during 2004-2005 on Little St. Simons Island.

Band combination [a]	Breeding Population	Arrival (First sighting)	Departure (Last sighting)	Residence Time (days)
YO-GX	Great Lakes	18 Jul 2004	11 Nov 2004	117 [b]
LO-GX	Great Lakes	17 Jul 2004	17 Feb 2005	216 [b]
OX-BY	Great Lakes	14 Jul 2004	6 Apr 2005	267
LX-LO	Great Lakes	21 Jul 2004	1 Jan 2005	165 [b]
b-YO	Great Lakes	18 Jul 2004	27 Apr 2005	284
b , -	Great Lakes	21 Jul 2004	27 Apr 2005	281
OO-LX	Great Lakes	17 Jul 2004	26 Nov 2004	133 [b]
- , O/RX	Great Lakes	14 Jul 2004	27 Apr 2005	288
O/LX-BO	Great Lakes	4 Aug 2004	8 May 2005	278 [c]
R/OX-OG	Great Lakes	23 Aug 2004	10 Mar 2005	200 [b, c]
- , Y/OX	Great Lakes	4 Aug 2004	3 May 2005	273
- , B/OX	Great Lakes	23 Aug 2004	8 May 2005	259
- , g/O/g	Great Lakes	26 Aug 2004	3 Jan 2005	131 [b]
- , BX	Great Lakes	22 Sep 2004	6 May 2005	212 [d]
- , LX	Great Lakes	13 Jul 2004	12 Mar 2005	240.5 [e]
mg-FwOR	Great Plains	14 Aug 2004	15 Dec 2004	123 [b]
mB-FwBG	Great Plains	24 Jul 2004	27 Dec 2004	156 [b]
- , X	Atlantic Coast	21 Jul 2004	18 Mar 2005	214.5 [f]
X, -	Atlantic Coast	31 Jul 2004	25 Apr 2005	204.5 [g]

[a] read left leg to right leg, separated by comma. Letters indicate color bands (L = black, X = metal, O = orange), lower case means light colored (b = light blue, but m = metal above tarsus), colored flag represented by Fw (white flag). Split band indicated by /
[b] individual defined to be a winter mortality (residence time until death)
[c] individual was captive-reared bird on breeding grounds
[d] three individuals with same band combination, but two individuals migrated through LSSI and another wintered, so residence times +/- 15 days
[e] three individuals with same band combination, but two individuals migrated through LSSI and another wintered, so residence times +/- 2.5 days
[f] three individuals with same band combination, but one individual migrated through LSSI and two wintered, so residence times +/- 25.5 days
[g] three individuals with same band combination, but one individual migrated through LSSI and two wintered, so residence time +/- 63.5 days, one individual was defined to be a winter mortality

Table 2.4 Median Arrival and Departure dates for all individually recognizable Piping Plovers during 2003-2004 and 2004-2005 on Little St. Simons Island. The departure dates do not include wintering individuals that were defined as winter mortalities. The standard errors were calculated using standard Julian Date format.

	Median Arrival Date (n)	Standard Error (d) Arrival (Range)	Median Departure Date (n)	Standard Error (d) Departure (Range)
2003-2004				
Great Lakes	3 Aug (23)	5.5 (19 Jul - 10 Oct)	20 Apr (14[a])	2.3 (7 Apr - 24 Apr)
Great Plains	12 Sep (7)	7.7 (7 Aug - 22 Sep)	20 Apr (3)	2.3 (16 Apr - 24 Apr)
Atlantic Coast	5 Oct (5)	13.3 (3 Aug - 15 Oct)	4 Apr (3)	5.0 (28 Mar - 20 Apr)
2004-2005				
Great Lakes	21 Jul (30)	4.1 (13 Jul - 3 Oct)	27 Apr (10[b])	4.5 (6 Apr - 8 May)
Great Plains	14 Aug (5)	6.7 (24 Jul - 2 Sep)	N/A (0[c])	N/A
Atlantic Coast	6 Aug (3)	6.6 (31 Jul - 22 Aug)	2 Apr (2[d])	6.5 (26 Mar - 8 Apr)

[a] two individuals that wintered defined to be winter mortalities.
[b] six individuals that wintered defined to be winter mortalities.
[c] no migrating individuals in spring (March and April) and two individuals that wintered defined to be winter mortalities.
[d] one individual that wintered defined to be a winter mortality

Table 2.5 Comparison of Piping Plover abundance on Little St. Simons Island to high counts from other Atlantic coast sites.

Site	Reference	Piping Plover Abundance	
		Winter [a]	Migration [b]
Little St. Simons Island, GA	this study	40 - 45 individuals 3.6 - 4.1 birds/km	80 - 85 individuals 7.3 - 7.7 birds/km
Monomoy NWR, MA	Dinsmore et al. (1998)	0	100 7.7 birds/km
Outer Banks, NC	Dinsmore et al. (1998)	very few	91 <1 bird/km
Chincoteague NWR, VA	Dinsmore et al. (1998)	0	50
Kiawah Island, South Carolina	Dodd et al. (1999)	30 1.9 birds/km	-
Deveaux Bank, South Carolina	Dodd et al. (1999)	24 3.4 birds/km	-
Georgia coast	Nicholls and Baldassarre (1990a)	105 0.8 birds/km	-
South Carolina coast	Nicholls and Baldassarre (1990a)	43 0.2 birds/km	-
Florida coast	Nicholls and Baldassarre (1990a)	24 0.04 birds/km	-
North Carolina coast	Nicholls and Baldassarre (1990a)	50 0.1 birds/km	-
Little St. Simons Island, GA	Ferland and Haig (2002)	25 2.2 birds/km	-
Little Talbot Island State Park	Ferland and Haig (2002)	26 3.0 birds/km	-
Florida coast	Ferland and Haig (2002)	111 2.3 birds/km	-
Cape Lookout N.S.; Shackleford Banks	Ferland and Haig (2002)	24 1.4 birds/km	-

[a] winter is defined to be January and February months. With exception to LSSI, numbers are listed as one census number and not means

[b] migration is defined to be July to October. With exception to LSSI, numbers are listed as one census number and not means

CHAPTER III

SPATIAL DISTRIBUTION AND SITE FIDELITY OF PIPING PLOVERS ON LITTLE ST. SIMONS ISLAND, GEORGIA

INTRODUCTION

Past monitoring (Haig and Oring 1985, Plissner and Haig 1997, Nicholls and Baldassarre 1990a, Dinsmore et al. 1998, Dodd et al. 1999, Ferland and Haig 2002), as well as my observations (Chapter 2), quantify abundance of Piping Plovers over an entire island or region. However, broad-scale data on abundance can be misleading (Van Horne 1983, Pulliam 1988), and any effective management plans for Piping Plovers will require fine-scale data on the movements of individuals among specific sites or habitats. The lack of data on the movement of wintering Piping Plovers limits our ability to identify the causes of continuing population declines (Johnson 1987) because events on the wintering grounds are likely to be a key source of mortality (Baker and Baker 1973). Gaining a better understanding of spatial distribution and site fidelity over a full nonbreeding season is prerequisite to understanding the role of habitat quality in the winter distribution of Piping Plovers.

Piping Plovers wintering on the Texas coast, monitored using radio telemetry during short time periods (36 - 68 days), showed strong signs of site fidelity within years (Drake et al. 2001). Johnson and Baldassarre (1988) found that Piping Plovers wintering in Alabama exhibited high among-year site fidelity, with more than 60% (12 of 19) of color-banded plovers returning to the same site the following season. High site fidelity within and between years might suggest that certain sites or habitats are disproportionately critical to conservation needs. However, the studies of Drake et al.

(2001) and Johnson and Baldassarre (1998) are the only ones to address this important issue for wintering Piping Plovers. Therefore, the goal of this study was to test the hypothesis that Piping Plovers wintering on Little St. Simons Island (LSSI) show high site fidelity both between and within years to specific beaches on the island. I predict that Piping Plovers on LSSI will show (1) high between-year site fidelity, (2) high within-year site fidelity to particular beaches, and (3) small winter home ranges.

METHODS

I collected data over a period of two consecutive study years, 2003-2004 and 2004-2005. Each study year began upon arrival of the first plovers in July and ended upon the departure of the final plover in May.

To explore site fidelity, I defined four sections of beach on LSSI (Fig. 3.1). These sections were physically separated or were separated by areas for which preliminary observations revealed low use by plovers. The northernmost beach, Sancho Panza Beach (ca. 1-km long; 31º 28’ 50” N 81º 28’ 50” W), was located closest to the Altamaha River at the north end of the island. It is physically separated from other beaches by two creeks (Sancho Panza Creek and Bass Creek), which drain the north end of the island. Bass Creek (ca. 1-km long; 31º 27’ 50” N 81º 27’ 50” W) was to the south of these two creeks, and it is a low-grade beach with a frequent washover zone during higher tides. There is little vegetation and dune development above the mean high tide mark. Middle Bar (ca. 2-km long; 31º 25’ 50” N 81º 27’ 50” W) was an emergent sandbar, bordered to the north and south by areas of little plover activity (> 60% of surveys resulted in no plovers in these areas). Inside the point at Middle Bar, there were shifting tidal pools and washover zones with no vegetation. Rainbow Beach (ca. 4.5-km long; 31º 22’ 50” N 81º 29’ 50”

W) was the largest section of beach, which extended from Mosquito Creek to the south end of the island. It had vegetated dunes and was eroding at the south tip.

As described in Chapter 2, during each census, I counted all color-banded and unbanded plovers for each section of beach. I also mapped the approximate position of all individually marked plovers using accurate maps and a hand-held Global Positioning System (GPS) unit (Garmin GPS 12 Personal Navigator). I defined color-banded individuals as migrants if they were not observed on the island between November and February, whereas individuals present during these months were defined as wintering individuals. Because of the thoroughness of the surveys, color-banded plovers that were not observed for a substantial period of time (4 weeks) were assumed to be absent from the island. I defined winter mortality as described in Chapter 2 (p. 26).

Of the individually recognizable color-banded individuals that wintered on LSSI in 2003-2004, I quantified the percentage of eligible individuals that returned in 2004-2005. I also quantified the percentage that wintered on the same beach section as in 2003-2004. Within each of the two study years, I quantified site fidelity as the percentage of observations of known plovers within each beach section. Some color-banded individuals possessed the same band combinations, and these plovers were not included in analysis of site fidelity.

Repeated surveys of a partially color-marked population gave me the opportunity to quantify the detection probability of some wintering Piping Plovers. I measured detection probability as the number of surveys on which an individual plover was seen divided by the total number of surveys. Detection probability was calculated only for color-banded plovers known to be wintering on LSSI.

Home-range size of wintering color-banded plovers on the beaches of LSSI was calculated from GPS coordinates using the fixed kernel method (including 95% and 50% core area; Worton 1989). The fixed kernel method was used because Seaman and Powell (1996) suggest this method produces the best home-range size estimates. Although these home ranges are based only on observations and not telemetry data, they are comparable to the only published study focusing on home-range estimates for Piping Plovers (Drake et al. 2001). Home ranges do not include possible movements off the island or into marsh areas (e.g., roosting). GPS coordinates were converted to Universal Transverse Mercator Grid system for ease of use with Arcview software, using Spatial Analyst and Animal Movement Extensions (Hooge and Eichenlaub 1997). Home-range sizes, reported in square kilometers, were calculated for individuals from each study year (2003-2004, 2004-2005).

I used JMP 3.0.2 (1994) for statistical analysis. Because home-range sizes and core areas were not normally distributed, I used nonparametric tests to compare space use. Site fidelity data were normally distributed, and I used Model I ANOVAs for 2003-2004 and t-tests for 2004-2005.

RESULTS

Throughout both study years, Piping Plover numbers varied among beach sections (Fig. 3.2). At low tide, when plovers were actively foraging, Sancho Panza Beach and Middle Bar consistently supported the most plovers. At high tide, when plovers were more likely to be roosting or loafing, plovers congregated at Bass Creek and Middle Bar. Rainbow Beach supported the fewest plovers, on average (Fig. 3.2).

Between-year site fidelity - During 2003-2004, 22 individually recognizable Great Lakes individuals, 6 Great Plains individuals, and 4 individuals from the Atlantic Coast were seen on LSSI. Thirteen (38.2%) of these were detected on LSSI in 2004-2005. Thirteen individually recognizable Great Lakes individuals, 3 Great Plains individuals, and 1 individual from the Atlantic Coast wintered on LSSI in 2003-2004. Two Great Lakes individuals were winter mortalities (see Chapter 2), one Great Plains individual died on its breeding grounds (C. Gratto-Trevor, Canadian Wildlife Service, pers.comm.), and the individual from the Atlantic Coast was recaptured on its breeding grounds and the distinctive color-band was removed (D. Amirault and J. McKnight, Canadian Wildlife Service, pers.comm.). This leaves 13 available to return to LSSI and be detected. Nine of the 13 (69.2%) individually recognizable plovers that wintered in 2003-20004 returned in 2004-2005 to exhibit between-year site fidelity (7 Great Lakes, 63.6%; 2 Great Plains, 100%). All nine wintered within the same section of beach both years (Table 3.1 and 3.2). Although I do not have data for 2005-2006 to estimate return rate in a second year, the pool of potential returning individuals will be smaller. This is because six of the nine color-banded wintering individuals were winter mortalities in 2004-2005 (see Chapter 2).

Within-year site fidelity – Piping Plovers showed strong fidelity to particular beaches on LSSI. During 2003-2004, only one Great Lakes plover occurred less than 75% of the time within the same section of beach (Table 3.1). Most sightings outside each individual's preferred section of beach occurred during migration (July to October and March to May). Great Lakes plovers did not exhibit stronger within-year site fidelity than the other two populations in 2003-2004 ($F = 3.04$, $df = 2, 16$ $p = 0.08$; Table 3.3).

During 2004-2005, nine of thirteen Great Lakes plovers occurred at least 72% of the time within the same section of beach (Table 3.2). Most observations outside an individual's preferred section of beach occurred during migration (July to October and March to May). Great Lakes plovers did not exhibit stronger within-year site fidelity than Great Plains plovers in 2004-2005 ($t = 1.12$, $df = 13$, $p = 0.28$; Table 3.3).

Detection probability - During 2003-2004, all wintering color-banded plovers were detected on an average of 43.7 surveys (range 25 - 57), and most plovers were detected more than 50% of the time (Table 3.3). All populations had similar detection rates in 2003-2004 ($F = 0.81$, $df = 2, 16$, $p = 0.46$). The detection rate during wintering months (November to February) for thirteen recognizable Great Lakes individuals was 54.7% (range 19.0% - 90.5%), with eight of these individuals detected at least 50% of the time. The detection rate for three Great Plains individuals during wintering months was 61.9% (range 57.1% - 66.7%), and the Atlantic Coast individual was detected on 76.2% of surveys (16/21 surveys).

During 2004-2005, all wintering color-banded plovers were detected on an average of 46.5 surveys (range 23 - 61) and more than 50% of the time (Table 3.3). Great Lakes plovers were not more detectable than Great Plains plovers in 2004-2005 ($t = 0.25$, $df = 13$, $p = 0.81$). During the wintering months (November to February), the detection rate for thirteen Great Lakes individuals was 71.4 % (range 45.5% - 90.0%). Eleven of the thirteen individuals were detected at least 50% of the time.

Home range - Home range sizes (i.e., size of beach areas used by Piping Plovers) during 2003-2004 and 2004-2005 demonstrate that plovers concentrated their activity on relatively small portions of LSSI (Table 3.4). Although LSSI has about 65 km^2 of beach and tidal flats, individual plovers used about 3 km^2. All populations had similar home range sizes and core areas in 2003-2004 (50%, $H = 0.05$, $df = 2$, $p = 0.97$; 95%, $H = 0.87$, $df = 2$, $p = 0.65$) and 2004-2005 (50%, $U = 17.0$, $p = 0.55$; 95%, $U = 15.0$, $p = 0.80$).

DISCUSSION

Piping Plovers exhibited modest between-year site fidelity, with 69.2% of the eligible wintering individuals from 2003-2004 returning to winter on LSSI in 2004-2005. This return rate is similar to that of reported in other shorebirds. Western Sandpipers exhibit higher than 50% return rates to wintering sites (Fernández et al. 2003), 89% of Redshanks show site fidelity between years (Burton 2000), and Semipalmated Sandpipers exhibit 67% across-year fidelity to their breeding grounds (Gratto et al. 1985). My results are also similar to return rates reported at other sites for Piping Plovers. Johnson and Baldassarre (1988) found that 63% of individuals color-banded on the wintering grounds in Alabama returned the following winter. In addition, Haig and Oring (1988) found 70% returned to their breeding areas in Manitoba.

Great Lakes individuals that returned to LSSI for a second wintering season were breeding adults banded no later than 2002 (J. Stucker, University of Minnesota, pers. comm.), and the two Great Plains individuals that returned to LSSI for a second wintering season were breeding adults banded in 2002 and 2003 as adults (C. Gratto-Trevor, Canadian Wildlife Service, pers. comm.). Older birds are known to be more likely to return to the same area than younger birds (Gratto et al. 1985, Haig and Oring 1988).

Piping Plovers wintering on LSSI showed fidelity to particular beaches and had small home ranges (Table 3.3 and Table 3.4). This implies that habitat quality on LSSI is sufficient to support Piping Plovers within relatively small areas. Within-year site fidelity has been documented in many wintering passerines (Snow and Snow 1960, Piper and Wiley 1990, Sherry and Holmes 1996, Plentovich et al. 1998) and a few wintering shorebirds (e.g. Sanderlings; Myers et al. 1979, Black Turnstones; Gill et al. 1983, Western Sandpipers; Warnock et al. 1997). Piping Plovers were > 69% site faithful to beach sections at the northern end of LSSI (Table 3.1 and Table 3.2). Dunlin radio-marked in Oregon indicated a high degree of site fidelity, but home-range sizes of 258.2 km^2 (95% minimum convex polygon; Sanzenbacher and Haig 2002), yet radio-marked Piping Plovers in Texas were site faithful throughout the fall, winter, and spring, and had home-range sizes of (95% kernel) 12.6 km^2 and mean core areas (50% kernel) of 2.9 km^2 (Drake et al. 2001). Although my observational data do not account for possible off island movements, the home-range size of beach areas on LSSI were small (3 km^2; Table 3.4). These smaller home range sizes could be attributable to high habitat quality and/or low human disturbance found on LSSI and other areas on the Georgia coast. I suggest these small movements could be used for careful management of Piping Plover habitats and human presence can help Piping Plovers (e.g. limit access to relative small areas). However, comparable data are needed from other islands.

Although site fidelity and censusing effort was high during this study, detection probability of color-banded Piping Plovers was modest, implying Piping Plovers could be commuting to other sites. Single surveys can result in underestimating the number of individuals at that site. Detection probability for other shorebirds is comparable as male Western Sandpipers wintering at a low quality site in Mexico was 74% for adults and 54% for juveniles (Fernández et al. 2003). Drake et al. (2001) averaged 54 observations of radio-marked Piping Plovers in Texas over 36-68 days. However, I observed individuals over the entire nonbreeding season (mean = 33 observations, range 69-283 days). Detection probability could have been higher during wintering months as a result of site fidelity and high habitat quality. Johnson and Baldassarre (1988) suggest winter censuses for Piping Plovers are best conducted during December and January. While I concur with this suggestion, it is important to note that surveys for Piping Plovers on the wintering grounds could be underestimating the number of individuals at those sites due to my modest detection probability within one season and even for individuals present over two consecutive wintering seasons.

High between-year site fidelity (69.2%) implies good winter survival. Wintering Dunlin and Western Sandpipers have been shown to vary in annual survivorship with first-year birds exhibiting lower survivorship than adults (Warnock et al. 1997, Fernández et al. 2003). Contrary to Drake et al.'s (2001) findings of high rates (100%) of survival in nonbreeding Piping Plovers, I found that 9.5% of color-banded wintering individuals (2/21) died in 2003-2004, and 47.3% of color-banded wintering individuals (9/19) died in 2004-2005 on LSSI (see Chapter 2). Because of the high 2004-2005 mortality, the opportunity for individually recognizable color-banded individuals to return in 2005-2006 is low. Thus, 2005-2006 fidelity will be < 50 %. However, at the time of this writing, four of the seven (57%) wintering individuals returned in 2005-2006 (pers. obs.). Between-year site fidelity must be variable, or 2004-2005 was an unusual year for Piping Plovers on the wintering grounds, but there is no clear cause.

Three of the thirteen Great Lakes individuals using Middle Bar (Fig. 3.1) died in 2004-2005, which suggests the habitat could have been negatively altered. In addition, one Great Plains individual, present on LSSI during both wintering seasons and frequently using Middle Bar, died in 2004-2005. Four hurricanes in 2004 (Hurricanes Charley, Frances, Ivan, and Jeanne), a fuel spill (approximately 25 Nov 2004) off the coast of Savannah (ca. 29 km), or random events from year to year could have been related to the change in spatial distribution of plovers at Middle Bar in 2004-2005. Food supplies in Rhode Island were greatly reduced and negatively affected breeding success and survival of Piping Plovers, following the North Cape oil spill in January 1996 (Donlan et al. 2003). These potential impacts could have contributed to the higher mortality rate (47.3%) in 2004-2005.

Throughout this study, I observed small movements, modest site fidelity and detection probability on LSSI. With four hurricanes and an oil spill 29 km off the coast of Savannah, it is possible these factors could have triggered prey shortages throughout the island, particularly south of the northern edge of the island. These spatial distribution data suggest something happened in 2004-2005, resulting in an obvious change in abundance and habitat use on LSSI. Although anecdotal, these observations suggest the spatial distribution of plovers and habitat suitability can change at a relatively fine spatial scale from year to year. I address habitat use and foraging behavior of Piping Plovers in Chapter 4.

Figure 3.1 Four sections of beach delineated to map spatial distribution of Piping Plovers on Little St. Simons Island during the 2003-2004 and the 2004-2005 study years. From north to south the sections are Sancho Panza Beach (1), Bass Creek (2), Middle Bar (3), and Rainbow Beach (4)

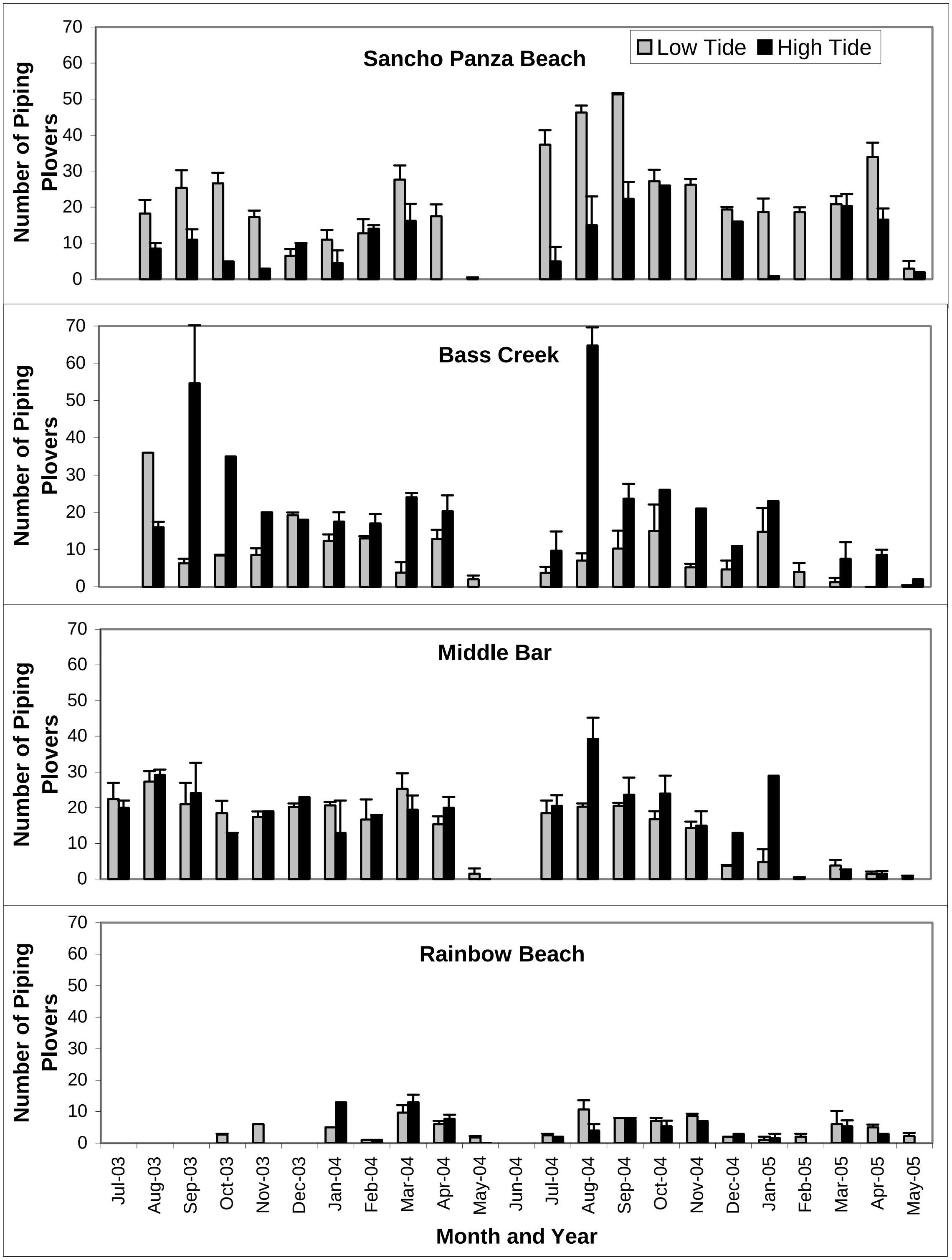


Figure 3.2 Number of Piping Plovers (mean ± SE) per month for each beach on Little St. Simons Island, July 2003 to May 2005 (range 2 - 10 surveys per month). Bars without standard error bars are due to one survey the entire month. Months without bars are due to no surveys conducted.

Table 3.1 Sightings by section of beach for individually recognizable wintering Piping Plovers during 2003-2004 on Little St. Simons Island. Site fidelity percentages are presented for the beach section in which each bird was most commonly observed.

Band combination [a]	n	Sancho Panza	Bass Creek	Middle Bar	Rainbow
Great Lakes					
YO-GX	36	2	1	32 (88.9%)	1
LO-GX	39	1	0	38 (97.4%)	0
OX-BY	32	31 (96.9%)	0	1	0
LX-LO	28	3	4	21 (75.0%)	0
b-YO	36	29 (80.6%)	7	0	0
b , -	22	3	19 (86.4%)	0	0
OO-LX	11	0	0	0	11 (100%)
OL-BX	27	23 (85.2%)	3	1	0
OX-BO [b]	11	7 (63.6%)	4	0	0
LO, -	30	27 (90.0%)	3	0	0
O/B, -	23	19 (82.6%)	1	3	0
- , O/Y [b]	16	14 (87.5%)	0	2	0
- , OX	24	24 (100%)	0	0	0
Great Plains					
mGG-FwO	36	23 (63.9%)	12	1	0
mg-FwOR	34	4	29 (85.3%)	1	0
mB-FwBG	35	7	4	24 (68.6%)	0
Atlantic Coast					
X-RL	27	1	0	26 (96.3%)	0

[a] read left leg to right leg, separated by comma. Letters indicate color bands (L = black, X = metal, O = orange), lower case means light colored (b = light blue, but m = metal above tarsus), colored flag represented by Fw (white flag). Split band indicated by /
[b] defined as a winter mortality (see Table 2.2)

Table 3.2 Sightings by section of beach for individually recognizable wintering Piping Plovers during 2004-2005 on Little St. Simons Island. Site fidelity percentages are presented for the beach section in which each bird was most commonly observed.

Band combination [a]	n	Sancho	Bass Creek	Middle Bar	Rainbow
Great Lakes					
YO-GX [b]	25	0	0	25 (100%)	0
LO-GX [b]	41	5	1	35 (85.4%)	0
OX-BY	43	31 (72.1%)	11	1	0
LX-LO [b]	32	12	4	16 (50.0%)	0
b-YO	58	47 (81.0%)	11	0	0
b , -	49	15	34 (69.4%)	0	0
OO-LX [b]	13	0	0	2	11 (84.6%)
- , O/RX	58	55 (94.8%)	3	0	0
- , B/OX	38	10	1	26 (68.4%)	1
O/LX-BO	46	44 (95.7%)	2	0	0
R/OX-OG [b]	22	3	14 (63.6%)	3	2
- , Y/OX	46	42 (89.4%)	4	0	0
- , g/O/g [b]	12	0	10 (83.3%)	2	0
Great Plains					
Mg-FwOR [b]	19	3	16 (84.2%)	0	0
MB-FwBG [b]	27	4	9	14 (51.9%)	0

[a] read left leg to right leg, separated by comma. Letters indicate color bands (L = black, X = metal, O = orange), lower case means light colored (b = light blue, but m = metal above tarsus), colored flag represented by Fw (white flag). Split band indicated by /
[b] defined as a winter mortality (see Table 2.3)

Table 3.3 Within-year site fidelity (percentage of observations within one beach section) and detection probability (percent of surveys on which an individual was seen) for individually recognizable wintering Piping Plovers on LSSI.

	n	Site Fidelity		Detection Probability	
		Mean ± SE	Range	Mean ± SE	Range
2003-2004					
Great Lakes	13	87.5 ± 2.9	63.6 - 100	56.9 ± 3.4	34.1 - 78.0
Great Plains	3	72.6 ± 6.1	63.9 - 85.3	66.4 ± 7.2	62.5 - 68.8
Atlantic Coast	1	96.3	N/A	64.3	N/A
All marked plovers	17	85.4 ± 2.9	63.6 - 100	59.0 ± 3.0	34.1 - 78.0
2004-2005					
Great Lakes	13	81.6 ± 3.8	50.0 - 96.2	73.5 ± 3.7	50.0 - 90.2
Great Plains	2	69.9 ± 9.8	55.6 - 84.2	71.0 ± 9.5	69.2 - 72.7
Atlantic Coast	0 [a]	Unknown	Unknown	Unknown	Unknown
All marked plovers	15	80.0 ± 3.6	50.0 - 96.2	73.1 ± 3.4	50.0 - 90.2
2003-2005					
Great Lakes	7	83.1 ± 4.7	61.7 - 93.4	69.8 ± 3.1	55.8 - 81.1
Great Plains	2	73.1 ± 8.8	61.3 - 84.9	67.8 ± 5.8	66.7 - 68.9
All marked plovers	9	81.9 ± 4.1	61.3 - 93.4	69.3 ± 2.6	55.8 - 81.1

[a] three banded plovers believed to be from population, but not individually recognizable.

Table 3.4 Home-range and core areas (mean ± SE) for individually recognizable wintering Piping Plovers from each breeding population on Little St. Simons Island.

	n	50% AK km^2		95% AK km^2	
		mean ± SE	Range	mean ± SE	Range
2003-2004					
Great Lakes	13	0.34 ± 0.07	0.038 - 0.763	1.75 ± 0.37	0.470 - 3.736
Great Plains	3	0.37 ± 0.15	0.078 - 0.802	2.52 ± 0.77	0.660 - 5.913
Atlantic Coast	1	0.18 ± N/A	N/A	0.83 ± N/A	N/A
2004-2005					
Great Lakes	13	0.77 ± 0.27	0.046 - 2.477	3.79 ± 1.09	0.221 - 9.903
Great Plains	2	1.48 ± 0.68	0.126 - 2.843	5.35 ± 2.79	0.896 - 9.807

CHAPTER IV

HABITAT USE AND FORAGING BEHAVIOR OF PIPING PLOVERS ON LITTLE ST. SIMONS ISLAND, GEORGIA

INTRODUCTION

Investigations on the winter ecology of the Piping Plover are scarce and focus primarily on density and distributions (Haig and Oring 1985). Little is known about the diet or foraging behavior of the Piping Plover during any part of its annual cycle (U.S. Fish and Wildlife 1985). Cuthbert et al. (1999) suggest that direct observations of food preference and foraging ecology are needed to better understand critical habitat designation and use. Furthermore, the abundance and diversity of organisms present in the habitat in which these birds are foraging allows us to gain a better understanding of the diet of Piping Plovers (Whyte 1985, Nordstrom 1990).

Based on the few studies that exist, we know that wintering Piping Plovers prefer to forage on mudflats and sandflats (Johnson and Baldassarre 1988, Nicholls and Baldassarre 1990b, Zonick 2000). Plovers spend > 75% of their time foraging (Johnson and Baldassarre 1988, Zonick 2000). These data suggest Piping Plovers maintain high foraging efforts during midwinter. Only one study has investigated the diet of nonbreeding Piping Plovers. This study occurred on Texas beaches, in which nonbreeding Piping Plovers prefer the polychaete, *Scolelepis squamata* (Zonick 2000). Breeding Piping Plovers in Quebec prefer organisms from the family Staphylinidae (insect; Shaffer and Laporte 1994). However, breeding Piping Plovers on the beaches of Nova Scotia were found to feed predominately on marine worms (Cairns 1977). Currently, no study has addressed the winter foraging ecology on the Atlantic coast.

Because there are large gaps in available data about diets and foraging ecology of wintering Piping Plovers (Patterson et al. 1990), my objective is to quantify the foraging ecology of wintering Piping Plovers on different beaches on Little St. Simons Island (LSSI), Georgia. Specifically, I tested the hypothesis that Piping Plovers have greater foraging success on certain beaches and that this difference is correlated with differences in prey abundance and sediment composition. This study should give us a better understanding of the habitat needs for Piping Plovers wintering on the Atlantic coast.

METHODS

I collected data over a period of two consecutive study years, 2004-2005 and 2005-2006. Each study year began at the beginning of the wintering season (November) and continued until March in 2005 and February in 2006.

Once the relative frequency with which plovers used different sections of the island (based on cumulative observations within sections of beaches; see Chapter 3) was determined, I measured features of the habitat within each of the three most frequently used beaches (Fig. 4.1). Only three beaches were measured because Piping Plovers used Bass Creek (Fig. 3.1) primarily at high tide for roosting (see Chapter 3). First, to better understand how the behavior of individual plovers may be related to prey abundance and plover density, I conducted focal animal observations a minimum of once every two weeks (November - March) using a spotting scope (Leica Televid, 20x-60x) at distances of 10 - 20 m. For each focal observation, one focal plover was picked haphazardly, and behavioral events were recorded for 5 min (number of foraging attempts, proportion of attempts that were successful, number of preening maneuvers, and number of agonistic interactions with other shorebirds). I dictated my observations into a digital recorder (OlympusVN-120). All behaviors were quantified as events per minute.

After gathering focal observations, I collected a sediment core (5-cm diameter and 10-cm depth; Weber and Haig 1997) in the approximate area (10 m^2) in which the plover was foraging. Sediment cores were sieved (U.S.A. Standard Testing Sieve, numbers 18 and number 35) and washed on location to isolate visible invertebrates from the substrate using a sieve number 18 (1 mm, 16 mesh) stacked on top of sieve number 35 (500 µm, 32 mesh). I counted all visible invertebrates isolated from the sediment cores and placed them in small glass vials for preservation (as long as 2 years) in isopropyl alcohol. I used a stereoscope (10X) to identify invertebrates to the lowest taxonomic level possible.

Finally, I quantified features of beach structure, such as grain size and organic content. Following sediment core collections for prey, I collected a separate sediment core adjacent to the prey sample (5-cm diameter and 10-cm depth; Weber and Haig 1997). In addition, I collected sediment samples on beaches with little Piping Plover activity. Sediment samples were dried (ca. 200°C for 2 h) in a Thelco Model 28 GCA/Precision Scientific Oven. The dried sample was placed into the top sieve of a stack from 0.250 - 2.250 phi (φ) and shaken on a Retsch AS200 Analytical Sieve Shaker for 10 min at a vibration height of 2.5 mm. The residue from this stack of sieves was transferred to the top of the next stack of sieves from 2.50 - 4.50 phi (φ) and shaken for 10 min at a vibration height of 2.5 mm. After shaking, I emptied each sieve sequentially into a weighing dish and weighed the sediment on a Mettler P120 analytical scale (± 0.01 g). The mass of sand retained on each sieve was used to calculate the mass fraction retained on that sieve for each sample. I quantified whether the physical composition of the beaches differed using the Udden-Wentworth grain-size scale, which groups sediments into five classes: coarse (0.25 - 1.0 phi [φ]), medium (1.25 - 2.0 φ), fine (2.25 - 3.0 φ), very fine (3.25 - 4.0 φ) and coarse silt (4.25 - >4.5 φ).

I analyzed data using JMP 3.0.2 (1994). Because some data (foraging attempts, % foraging success) were normally distributed in 2004-2005, I used a Model I ANOVA to test for differences among beaches (Sancho Panza Beach, Main Beach, and Rainbow Beach). I compared Sancho Panza Beach and Main Beach foraging attempts and successes during the 2005-2006 study year using t-tests. I used nonparametric tests to test for differences among beaches for data that were not normally distributed.

RESULTS

Piping Plovers foraged most commonly within two of the three beach sections: Sancho Panza Beach and Main Beach. Rainbow Beach was used less frequently and supported lower abundances of Piping Plovers (see Chapter 3). Piping Plovers used Bass Creek (Fig. 3.1) primarily at high tide for roosting.

Piping Plovers averaged 15.1 ± 0.7 (SE; 0.3 - 38.4; $n = 104$) foraging attempts/min. During 2004-2005, Piping Plovers on Rainbow Beach made more foraging attempts/min than plovers on other beaches ($F = 3.59$, $df = 2, 76$, $p = 0.03$; Table 4.1). During 2005-2006, only one focal observation occurred on Rainbow Beach. Piping Plovers foraged at similar rates on Main Beach and Sancho Panza Beach ($t = 1.29$, $df = 24$, $p = 0.21$). Piping Plovers averaged 4.5 ± 0.29 (0 - 17; $n = 104$) foraging successes/min. During 2004-2005 and 2005-2006, success rates did not differ among beaches ($H = 2.31$, $df = 2$, $p = 0.31$; $t = 0.67$, $df = 24$, $p = 0.51$; Table 4.1).

The relative foraging success for Piping Plovers (number of successes divided by total attempts during each focal observation) averaged 30.3 ± 1.6% (0 - 88.9; $n = 104$). During 2004-2005, Piping Plovers on Sancho Panza Beach foraged more successfully than plovers on other beaches ($F = 4.77$, $df = 2, 76$, $p = 0.01$; Table 4.1). Because there was only one focal observation on Rainbow Beach (13.1% foraging success) these two beaches could not be compared during 2005-2006 (Table 4.1). Piping Plovers on Sancho Panza Beach did not forage more successfully than plovers on Main Beach during 2005-2006 ($U = 57.0$, $p = 0.79$). However, over both study years, Piping Plovers on Sancho Panza Beach foraged more successfully than plovers on Rainbow Beach ($H = 9.57$, $df = 2$, $p < 0.01$).

Some individually recognizable color-banded plovers were observed more than once. One adult from the Great Lakes population observed faithfully on Sancho Panza Beach, exhibited the highest relative foraging success (40.3% ± 5.3%, $n = 6$) from both study years, and another adult from the Great Lakes population, which was defined as a winter mortality in 2004-2005 (see Chapter 3), exhibited the lowest relative foraging success (20.2% ± 9.3%, $n = 2$) on Main Beach. Relative foraging success of individual color-banded plovers did not vary significantly among individuals ($F = 0.66$, $df = 8, 31$, $p = 0.72$). Two captive-reared individuals from the Great Lakes population exhibited similar relative foraging success (35.6% ± 5.9%, $n = 5$, and 31.6% ± 6.6%, $n = 4$) to breeding adults and other color-banded individuals.

Piping Plovers averaged 0.12 ± 0.03 ($n = 104$) agonistic events/min with other plovers and shorebirds. During 2004-2005, plovers from Sancho Panza Beach averaged 0.21 ± 0.05 (0 - 1.25; $n = 41$) agonistic events per minute. Plovers from Main Beach and

Rainbow Beach averaged only 0.08 ± 0.03 (0 - 1.80; n = 26) and 0 (n = 12), respectively. Piping Plovers on Sancho Panza Beach interacted significantly more than plovers on Main and Rainbow Beach ($H = 10.15$, $df = 2$, $p < 0.01$) during 2004-2005. During 2005-2006, Piping Plovers on Sancho Panza Beach did not interact more than plovers from other beaches.

A total of 76 prey samples was taken in the field during both study years, with 32 becoming resource samples preserved in isopropyl alcohol for identification. Polychaetes were the most common visible invertebrate found in the sediment samples. Of the invertebrates identified, the most common polychaete was *Nereis sp*. Other prey items identified, but in considerably lower densities, included another polychaete, an amphipod, an isopod, and Diptera larvae (Table 4.2). During 2004-2005, polychaetes were more abundant on Sancho Panza Beach than on Rainbow Beach ($H = 9.72$, $df = 2$, $p < 0.01$). Eighty-six percent of samples on Sancho Panza Beach contained polychaetes (5.8 ± 0.8 per sample); only 12.5% of samples contained polychaetes on Rainbow Beach (0.9 ± 0.9 per sample). During 2005-2006, Sancho Panza Beach (5.2 ± 1.4 per sample) did not have more polychaetes than Main Beach (5.0 ± 1.9 per sample; $U = 36.0$, $p = 0.96$).

Coarse, medium, and fine sand occurred in similar proportions on all three beaches. However, very fine sand and coarse silt occurred in significantly higher proportions than the proportions on Sancho Panza Beach than on Rainbow Beach and Main Beach (Table 4.3). I collected 22 sediment samples from the same location as focal observations of foraging behavior. Foraging attempts/min was not correlated with very fine ($r = 0.21$, $n = 22$, $p = 0.35$) or coarse silt sand ($r = -0.03$, $n = 22$, $p = 0.89$). Foraging success/min was not correlated with very fine ($r = 0.32$, $n = 22$, $p = 0.14$) and coarse silt sand ($r = 0.16$, $n = 22$, $p = 0.48$). Relative foraging success also did not significantly correlate with very fine ($r = 0.24$, $n = 22$, $p = 0.28$) and coarse silt sand ($r = 0.23$, $n = 22$, $p = 0.30$). I collected 19 sediment samples from the same location as prey samples. Polychaete abundance did not significantly correlate with very fine ($r = 0.21$, $n = 19$, $p = 0.40$) or coarse silt sand ($r = 0.29$, $n = 19$, $p = 0.23$).

DISCUSSION

My results provide the most detailed data on habitat use and foraging behavior for wintering Piping Plovers on the Atlantic coast. These data permit three important conclusions about Piping Plover winter ecology in coastal Georgia.

First, Piping Plover habitat use can vary significantly within one relatively small island, thus considering all of LSSI as critical habitat is overlooking subtleties. Nicholls and Baldassarre (1990b) found that 72% of sites along the Atlantic coast with Piping Plovers were adjacent to large inlets and passes. In addition, non-vegetated beaches associated with bays, inlets, and lagoons, particularly tidal flats, are habitats favored by Piping Plovers and other shorebirds (Withers 2002). The north end of LSSI is located at the mouth of the Altamaha River Delta with more expansive tidal flats than the southern portions of the island. Furthermore, there is no vegetation throughout these tidal flats on the north end of LSSI. With large densities of Piping Plovers documented (see Chapter 3) within this area, these data help define habitat needs for wintering Piping Plovers on the Atlantic coast. These high densities of Piping Plovers on the north end of LSSI could be related to higher foraging success. Piping Plovers on the north end of LSSI attempted to forage less, yet they were more successful compared to the southern portions of the island, suggesting plovers on the north end were more efficiently foraging.

Second, prey abundance varied among sites in a way consistent with foraging data. The prey abundance on the north end of LSSI was significantly higher than southern portions of the island, which was consistent with plover abundance (see Chapter 3). Zonick (2000) found benthic prey densities to be higher around lagoon ecosystem barrier island flats than at mainland flats, and concluded that the higher use of barrier islands was a preference by Piping Plovers for more productive feeding areas. Currently, no study has investigated prey requirements for wintering Piping Plovers on the Atlantic coast. I rarely observed Piping Plovers feeding on prey other than marine polycheates; therefore, *Nereis sp.*, the most commonly found and identified polychaete, appears to be an important food source for wintering Piping Plovers in coastal Georgia. This polychaete is commonly found on Atlantic coast beaches and it is possible maintaining *Nereis sp.* population numbers in Piping Plover wintering areas exposed to human recreation can result in effective Piping Plover habitat on the Atlantic coast. There is a need for further research on actual invertebrate abundance and diet with an emphasis on fecal samples in occupied Piping Plover habitats.

Third, I found quantifiable physical distinctions characterizing frequent habitat use by Piping Plovers. Only one study has characterized sediment composition on the Atlantic coast and found higher numbers of Piping Plovers in habitats with higher percent silt (Nicholls and Baldassarre 1990b). I investigated the sediment at a finer scale and found that coarse silt and very fine sand on the northern beach of LSSI were significantly more abundant than other beaches on LSSI. Fraser (2001) suggested that, although politically difficult, an approach to conserving moist substrate ecosystems is to find places with natural processes of overwash, island breaching, and sand transport unaffected by human densities. My study has investigated these parameters and considering beach reclamation projects and human recreation use of beaches, these sediment data could be considered for effective management plans when re-nourishment beach projects or other beach management plans threaten current Piping Plover habitats on the Atlantic coast. Furthermore, these data could be used for guidelines in attempts to create optimum Piping Plover habitat during re-nourishment projects. Future studies could focus on the relationship between sediment composition and prey abundance.

In conclusion, my results suggest that Piping Plovers use specific microhabitats along the Georgia coast, and these habitat preferences may be dependent on prey abundance and sediment composition. Other areas along the Atlantic coast, particularly the Georgia coast, may need similar features of habitat for sufficient Piping Plover habitat use. According to the Coastal Georgia Regional Development Center (2004), coastal Georgia has been designated as the second fastest growing region in the state behind Atlanta (Coastal Georgia Regional Development Center 2004). We now have a better understanding of the important features of habitat associated with Piping Plovers on an undeveloped island within the Georgia coast. With increasing population growth, all Georgia beaches and the remaining wintering grounds on the Atlantic coast are of high conservation concern. It is imperative that we gain a better understanding of the foraging behavior and habitat uses of wintering Piping Plovers, especially throughout coastal Georgia. An important goal of Piping Plover management on the Atlantic coast should be to provide habitats absent from vegetation, adjacent to inlets, rivers, or bays, and large tidal flats consisting of some coarse silt and very fine sand. However, further research is needed throughout the wintering range on the Atlantic coast to validate these findings in areas of higher disturbance and human interactions.

Figure 4.1 Beaches used for foraging behavior and habitat use on Little St. Simons Island, Georgia: (1) Sancho Panza Beach, (2) Main Beach, and (3) Rainbow Beach.

Table 4.1. Foraging rate, percent success, and polychaete abundance (mean ± SE) for each beach during 2004-2005 and 2005-2006 on Little St. Simons Island. Foraging attempts are the mean number of mouth attacks per minute. Success rate percentages are minimum success rates from total attempts versus total successes during focal observations through a spotting scope.

Beach	Focal observations (n)	Foraging Attempts/min (Range)	% Successful (Range)	Polychaete Abundance (Range)
2004-2005				
Sancho Panza Beach	41	12.5 ± 1.2 (0.3 - 26.8)	35.3 ± 2.6 % (0 - 88.9)	5.76 ± 0.91 (0 - 15)
Main Beach	24	15.1 ± 1.5 (2.4 - 31.8)	27.5 ± 3.4 % (0 - 51.4)	6.30 ± 1.10 (0 - 24)
Rainbow Beach	12	18.9 ± 2.2 (8 - 38.4)	19.5 ± 4.8 % (0 - 49.5)	1.00 ± 1.86 (0 - 7)
All beaches	77	14.3 ± 0.9 (0.3 - 38.4)	30.4 ± 2.0 % (0 - 88.9)	5.36 ± 0.68 (0 - 24)
2005-2006				
Sancho Panza Beach	21	17.4 ± 1.0 (4.5 - 25.2)	31.9 ± 2.1 % (0 - 44.7)	5.21 ± 1.34 (0 - 20)
Main Beach	5	14.6 ± 2.0 (10.6 - 20)	34.9 ± 4.4 % (32.9 - 38.6)	5.00 ± 2.25 (0 - 11)
Rainbow Beach	1	21.4	13.1%	0
All beaches	27	17.0 ± 0.9 (4.5 - 25.2)	31.8 ± 2.0 % (0 - 44.7)	4.90 ± 1.13 (0 - 20)

Table 4.2 Potential prey items identified from sediment samples (volume = 196.35 cm^3) collected on Little St. Simons Island during 2004-2005 and 2005-2006.

Beach	Prey Samples (n)	Prey Items Found	Total animals
Sancho Panza Beach	20	*Nereis sp.*	83
		Polychaete, unidentified	3
		Amphipod, unidentified	13
Main Beach	8	*Nereis sp.*	22
		Polychaete, unidentified	7
		Diptera larvae	1
		Amphipod, unidentified	2
Rainbow Beach	4	*Nereis sp.*	4
		Amphipod, unidentified	13
		Asellid isopod	1

Table 4.3 Grain size proportions (mean ± SE) for each beach on Little St. Simons Island during 2005-2006. Particle sizes on each beach are reported as a percentage of the total sample.

Particle Size (φ)	Sancho Panza Beach (n=17)	Main Beach (n=7)	Rainbow Beach (n=4)	p-value
0.25 - 1.0 (Coarse)	6.341 ± 1.895 (0.251 - 30.920)	5.157 ± 2.065 (0.540 - 14.582)	1.840 ± 0.754 (0.733 - 4.029)	0.47 [a]
1.25 - 2.0 (Medium)	14.599 ± 2.626 (1.979 - 40.078)	14.884 ± 2.583 (6.329 - 24.815)	16.063 ± 1.346 (13.602 - 18.459)	0.96 [b]
2.25 - 3.0 (Fine)	67.080 ± 3.806 (25.573 - 89.368)	76.610 ± 3.364 (67.204 - 87.783)	76.219 ± 1.406 (72.953 - 79.685)	0.19 [a]
3.25 - 4.0 (Very Fine)	11.628 ± 1.573 (3.330 - 22.848)	3.213 ± 0.383 (1.388 - 4.129)	5.804 ± 0.870 (4.436 - 8.209)	< 0.01 [a]
4.25 - > 4.5 (Coarse Silt)	0.352 ± 0.060 (0.098 - 0.812)	0.137 ± 0.033 (0.059 - 0.309)	0.075 ± 0.019 (0.029 - 0.121)	< 0.01 [a]

[a] Kruskal-Wallis tests

[b] Model I ANOVA

CHAPTER V

CONCLUSIONS

The Piping Plover (*Charadrius melodus*) is a federally listed species with three distinct breeding populations. Virtually all the conservation-related research has focused on the breeding season despite the fact that Piping Plovers spend only 3-4 months there. Of the studies conducted on the wintering grounds, almost all have occurred on the Gulf coast. Even with these studies on the wintering grounds, we still lack understanding about the distribution, abundance, and winter ecology of the Piping Plover. An effective recovery plan for this species continues to be hindered by the lack of knowledge about their winter distribution and winter habitat use along the Atlantic coast (Plissner and Haig 1997). Thus, my study has important implications for management plans for wintering Piping Plovers.

First, the critical habitat designation is justified for Little St. Simons Island (LSSI), Georgia. I found that LSSI supports a substantial number of migrating and wintering Piping Plovers, especially individuals from the Great Lakes population. No other site along the Atlantic coast has been documented with more than 100 Piping Plovers during migration or 30 during mid-January, yet LSSI surpassed these numbers (Table 2.5). Furthermore, in 2004-2005 alone, 40 Great Lakes individuals, a significant percentage (20%) of the entire breeding population, were documented on LSSI. Future work should now extend to detailed surveys of other sites within the Altamaha Rive Delta and the rest of the Georgia and Atlantic coast.

Second, all three breeding populations of Piping Plovers seem to follow similar schedules for arrivals, residence, and departure. Therefore, there is no need for population-specific protection or management on LSSI. Individuals from the most endangered population (Great Lakes) are present on LSSI throughout 10-month wintering season. However, there were no more than three wintering individuals from the Great Plains and Atlantic Coast populations. Thus, the current moratorium on color-banding Atlantic Coast plovers limits the resolution with which I could monitor movements of birds from this population. I suggest that managers consider greater banding effort for Atlantic Coast individuals in order to permit detailed studies of winter movements such as those I report here for Great Lakes Piping Plovers.

Third, high fidelity between (69%) and within (69%) years, as well as small home ranges suggest the development or degradation of very local areas could result in negative impacts on wintering Piping Plovers. The large number of mortalities associated with a single LSSI beach in 2004-2005 certainly suggests that local events may have serious consequences for wintering Piping Plovers. The disturbance to key areas on LSSI (e.g. Sancho Panza Beach) could be detrimental for migrating and wintering Piping Plovers, especially those from the Great Lakes population. However, careful people management could allow some coexistence within islands for Piping Plovers. I suggest that managers consider winter residence could be tied to very local areas within one site itself.

Fourth, moderate detection probabilities (ca. 50% chance of detection per survey) suggest single surveys are inadequate for precise estimates of Piping Plover abundance during winter. Even with individuals known to be residents for consecutive seasons the detection probability was modest. Although it is likely that single surveys conducted during the wintering seasons will underestimate the number of Piping Plovers at individual sites, in the absence of even more extensive marking it will be difficult to quantify what proportion of a Piping Plover winter population is detected by a single survey. I recommend more work be conducted in this important area.

Finally, Piping Plover foraging behavior varies among beaches on the same island and is broadly correlated with habitat features. These data suggests we may be able to relate site fidelity in Piping Plovers to specific features of local habitats. In particular, Piping Plover abundance may be predicted based on polychaete abundance and sediment composition. I suggest managers investigate the possibility that non-vegetated beaches near estuarine systems with higher coarse silt and very fine sand proportions are the optimum habitats preferred by foraging plovers.

In conclusion, my results contribute to the understanding of winter ecology of the Piping Plover on the Atlantic coast. The findings of my research have documented the abundance, seasonal patterns, spatial distribution, site fidelity, and habitat uses of Piping Plovers on LSSI, Georgia. Considering the federal status of Piping Plovers, LSSI is one of the most important sites on the Atlantic coast for the Piping Plover, especially individuals from the Great Lakes population. This study may bring us closer to quantifying limiting factors that affect Piping Plovers throughout its wintering range.

LITERATURE CITED

Amirault, D.L., J. McKnight, F. Schaffer, K. Baker, L. MacDonnell, and P. Thomas. 2006. Novel anodized aluminum bands cause leg injuries in Piping Plovers. Journal of Field Ornithology 77:18-20.

Baker, M.C., and A.E.M. Baker. 1973. Niche relationships among six species of shorebirds on their wintering and breeding ranges. Ecological Monographs 43:193-212.

Baker, A.J., P. M. Gonzalez, T. Piersma, L.J. Niles, I. de Lima Serrano do Nascimento, P.W. Atkinson, N.A. Clark, C.D.T. Minton, M.K. Peck, and G. Aarts. 2004. Rapid population decline in Red Knots: fitness consequences of decreased refueling rates and late arrival in Delaware Bay. Proceedings of the Royal Society B: Biological Sciences 271:875-882.

Burton, N.H.K. 2000. Winter site-fidelity and survival of Redshank (*Tringa totanus*) at Cardiff, South Wales. Bird Study 47:102-112.

Butler, R.W., F.S. Delgado, H. de la Cueva, V. Pulido, and B.K. Sandercock. 1996. Migration routes of the Western Sandpiper. Wilson Bulletin 108:662-672.

Coastal Georgia Regional Development Center. 2004. A summary of Georgia's Regional Development Centers: their purpose, function, and programs. Great Southern Publishers, Inc., Atlanta, Georgia. 134 pp.

Cairns, W.E. 1977. Breeding biology and behaviour of the Piping Plover, *Charadrius melodus*, in southern Novia Scotia. M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia. 100 pp.

Clark, K.E., L.J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. Condor 95:694-705.

Cuthbert, F.J., B. Scholtens, L.C. Wemmer, and R. McLain. 1999. Gizzard contents of Piping Plover chicks in Northern Michigan. Wilson Bulletin 111:121-123.

Dinsmore, S.J., J.A. Collazo, and J.R. Walters. 1998. Seasonal numbers and distribution of shorebirds on North Carolina's Outer Banks. Wilson Bulletin 110:171-181.

Dodd, S.L., M.D. Spinks, and P.M. Wilkinson. 1999. Abundance and distribution of wintering Piping Plovers on the coast of South Carolina: findings from the 1997, 1998, and 1999 mid-winter censuses. The Chat 63:155-166.

Donlan, M., M. Sperduto, and C. Hebert. 2003. Compensatory mitigation for injury to a threatened or endangered species: scaling piping plover restoration. Marine Ecology Progress Series 264:213-219.

Drake, K.R., J.E. Thompson, K.L. Drake, and C. Zonick. 2001. Movements, habitat use, and survival of nonbreeding Piping Plovers. Condor 103:259-267.

Ferland, C.L., and S.M. Haig. 2002. 2001 International Piping Plover Census. U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon. 293 pp.

Fernández, G., H. de la Cueva, N. Warnock, and D.B. Lank. 2003. Apparent survival rates of Western Sandpiper wintering in northwest Baja California, Mexico. Auk 120: 55-61.

Fraser, J.D. 2001. Moist substrate habitats for Piping Plovers on the Atlantic and Gulf of Mexico coasts. Proceedings of the Coastal Ecosystems and Federal Activities Technical Training Symposium, Gulf Shores, Alabama. 11 pp.

Gill, Jr. R.E., C.M. Handel, and L.A. Shelton. 1983. Memorial to a Black Turnstone: an examplar of breeding and wintering site fidelity. North American Bird Bander 8:98-101.

Gratto, C.L., R.I.G. Morrison, and F. Cooke. 1985. Philopatry, site tenacity, and mate fidelity in the Semipalmated Sandpiper. Auk 102:16-24.

Haig, S.M. 1985. The status of the Piping Plover in Canada. Report prepared for the Committee on the Status of Endangered Wildlife in Canada. National Museum of Canada, Ottawa.

Haig, S.M. 1992. Piping Plover. No. 2 Birds of North America. A. Poole, P. Stettenheim and F. Gill, eds. American Ornithologists' Union, Philadelphia, Pennsylvania.

Haig, S.M., and L.W. Oring. 1985. Distribution and status of the Piping Plover throughout the Annual Cycle. Journal of Field Ornithology 56:334–335.

Haig, S.M., and L.W. Oring. 1988. Mate, site, and territory fidelity in Piping Plovers. Auk 105:268-277.

Haig, S.M., and J.H. Plissner. 1992. 1991 International Piping Plover Census. United States Fish and Wildlife Service. Report USFWS Region 3, Division of Endangered Species, Fort Snelling, Minnesota. 148 pp.

Haig, S.M., C.L. Ferland, F.J. Cuthbert, J. Dingledine, J.P. Goosen, A. Hecht, and N. McPhillips. 2005. A complete species census and evidence for regional declines in Piping Plovers. Journal of Wildlife Management 69:160-173.

Harrington, B.A., J.M. Hagan, and L.E. Leddy. 1988. Site fidelity and survival differences between two groups of New World Red Knots (*Calidris canutus*). Auk 105:439-445.

Hitchcock, C.L. and C. Gratto-Trevor. 1996. Diagnosing a shorebird local population decline with a stage-structured population model. Ecology 78:522-534.

Hooge, P., and B. Eichenlaub. 1997. Animal movement extension to arcview. Version 1.1 Alaska Science Center - Biological Science Office, U.S. Geological Survey, Anchorage, Alaska.

Howe, M.A., P.H. Geissler, and B.A. Harrington. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation 49:185-199.

JMP Version 3.0.2. 1994. SAS Institute, Inc. Cary, North Carolina.

Johnson, C.M. 1987. Aspects of wintering ecology of piping plovers in coastal Alabama. M.Sc. thesis, Auburn University, Auburn, Alabama.

Johnson, C.M., and G.A. Baldassarre. 1988. Aspects of the wintering ecology of Piping Plovers in coastal Alabama. Wilson Bulletin 100:214–223.

Morrison, R.I.G., Y. Aubry, R.W. Butler, G.W. Beyersbergen, G.M. Donaldson, C.L. Gratto-Trevor, P.W. Hicklin, V.H. Johnston, and R.K. Ross. 2001. Declines in North American shorebird populations. Wader Study Group Bulletin 94:34-38.

Morrison, R.I.G, R.K. Ross, and L.J. Niles. 2004. Declines in wintering populations of Red Knots in southern South America. Condor 106:60-70.

Myers, J.P. 1981. Cross-seasonal interactions in the evolution of sandpiper social systems. Behavioral Ecology and Sociobiology 8:195-202.

Myers, J.P., P.G. Connors, F.A. Pitelka. 1979. Territory size in wintering Sanderlings: the effects of prey density and intruder density. Auk 96:551-561.

Myers, J.P., R.I.G. Morrison, P.Z. Antas, B.A. Harrington, T.E. Lovejoy, M. Sallaberry, S.E. Senner, and A. Tarak. 1987. Conservation strategy for migratory species. American Scientist 75:19-26.

Nicholls, J.L, and G.A. Baldassarre. 1990a. Winter distribution of Piping Plover along the Atlantic and Gulf coasts of the United States. Wilson Bulletin 102:400–412.

Nicholls, J.L., and G.A. Baldassarre. 1990b. Habitat associations of Piping Plovers wintering in the United States. Wilson Bulletin 102:581-590.

Nordstrom, L.H. 1990. Assessment of habitat suitability for reestablishment of Piping Plovers in the Great Lakes National Lakeshores. M.Sc. thesis, Missouri University, Colombia, Missouri.

O'Reilly, K.M., and J.C. Wingfield. 1995. Spring and Autumn migration in shorebirds: same distance, different strategies. Integrative and Comparative Biology 35:222-233.

Patterson, M.E., J.D. Fraser, and J.W. Roggenbuck. 1990. Piping Plover ecology, management and research needs. Virginia Journal of Science 41:419-426.

Pfister, C., B.A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biological Conservation 60:115-126.

Piersma, T., P. Wiersma, and J. van Gils. 1997. The many unknowns about plovers and sandpipers of the world: introduction to a wealth of research opportunities highly relevant for shorebird conservation. Wader Study Group Bulletin 82:23-33.

Piper, W.H., and R.H. Wiley. 1990. Correlates of range size in White-throated Sparrows, *Zonotrichia albicollis*. Animal Behavior 40:545-552.

Plentovich, S.M., N.R. Holler, and G.E. Hill. 1998. Site fidelity of wintering Henslow's Sparrows. Journal of Field Ornithology 69:486-490.

Plissner, J.H., and S.M. Haig. 1997. 1996 International Piping Plover Census. U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon. 230 pp.

Plissner, J.H., and S.M. Haig. 2000. Status of a broadly distributed endangered species: results and implications of the second international census. Canadian Journal of Zoology 78:128-139.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. The American Naturalist 132:652-661.

Sanzenbacher, P.M., and S.M. Haig. 2002. Residency and movement patterns of wintering Dunlin in the Willamette Valley of Oregon. Condor 104:271-280.

Seaman, D.E., and R.A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home-range analysis. Ecology 77:2075-2085.

Shaffer, F., and P. Laporte. 1994. Diet of Piping Plovers of the Magdalen Islands, Quebec. Wilson Bulletin 106:531-536.

Sherry, T.W., and R.T. Holmes. 1996. Winter habitat quality, population limitation, and conservation of neotropcial-nearctic migrant birds. Ecology 77:36-48.

Snow, D.W. and B.D. Snow. 1960. Northern Waterthrushes returning to the same winter quarters in successive winters. Auk 77:351-352.

U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; Determination of endangered and threatened status for the piping plover – Final rule. Federal Register 50(238):50726-50734.

U.S. Fish and Wildlife Service. 1994. Draft revised recovery plan for Piping Plovers, *Charadrius melodus*, breeding on the Great Lakes and Great Plains of the United States. USFWS, Twin Cities, Minnesota. 85 pp.

U.S. Fish and Wildlife Service. 1996. Piping Plover (*Charadrius melodus*), Atlantic Coast population, revised recovery plan. USFWS, Hadley, Massachusetts. 258 pp.

U.S. Fish and Wildlife Service. 2001. Endangered and threatened wildlife and plants: Final determination of critical habitat for wintering Piping Plovers. Federal Register 66(132):36037-36104.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

Warnock, N., G.W. Page, and B.K. Sandercock. 1997. Local survival of Dunlin wintering in California. Condor 99:906-915.

Warnock, N., S.M. Haig, and L.W. Oring. 1998. Monitoring species richness and abundance of shorebirds in the Western Great Basin. Condor 100:589-600.

Warnock, N., J.Y. Takekawa, and M.A. Bishop. 2004. Migration and stopover strategies of individual Dunlin along the Pacific coast of North America. Canadian Journal of Zoology 82:1687-1697.

Weber, L.M., and S.M. Haig. 1997. Shorebird diet and size selection of Nereid polychaetes in South Carolina coastal diked wetlands. Journal of Field Ornithology 68:358-366.

Wemmer, L. 1999. Piping Plover (*Charadrius melodus*) Great Lakes population. Revised recovery plan. Unofficial draft submitted to USFWS – Region 3, Fort Snelling, Minnesota. 75 pp.

Wershler, C., and C. Wallis. 1986. Status of the Piping Plover in Alberta, 1986. Unpublished report for World Wildlife Fund Canada and Canadian Wildlife Service, Calgary, Alberta. 54 pp.

Whyte, A. 1985. Breeding ecology of the Piping Plover, *Charadrius melodus*, in central Saskatchewan. M.Sc. thesis, University of Saskatchewan, Saskatoon, Saskatchewan. 153 p.

Withers, K. 2002. Shorebird use of coastal wetland and barrier island habitat in the Gulf of Mexico. The Scientific World Journal 2:514-536.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

Zonick, C.A. 2000. The winter ecology of Piping Plover (Charadrius melodus) along the Texas Gulf coast. Ph.D. dissertation, University of Missouri – Columbia, Columbia, Missouri. 182 pp.

APPENDICES

APPENDIX A

COLOR-BANDED PIPING PLOVERS DOCUMENTED ON LITTLE ST. SIMONS ISLAND BETWEEN 19 JULY 2003 AND 8 MAY 2005

Band Combination [a]	Breeding Population	Study years present on LSSI	Migrant/Wintering [b]
YO, GX	Great Lakes	2003-2004, 2004-2005	Wintering
LO, GX	Great Lakes	2003-2004, 2004-2005	Wintering
OX, BY	Great Lakes	2003-2004, 2004-2005	Wintering
LX, LO	Great Lakes	2003-2004, 2004-2005	Wintering
b, YO	Great Lakes	2003-2004, 2004-2005	Wintering
b, -	Great Lakes	2003-2004, 2004-2005	Wintering
OO, LX	Great Lakes	2003-2004, 2004-2005	Wintering
OL, BX	Great Lakes	2003-2004	Wintering
OX, BO	Great Lakes	2003-2004	Wintering
LO, -	Great Lakes	2003-2004	Wintering
O/B, -	Great Lakes	2003-2004	Wintering
- , O/Y	Great Lakes	2003-2004	Wintering
- , OX	Great Lakes	2003-2004	Wintering
- , YX	Great Lakes	2003-2004	Wintering
- , YX	Great Lakes	2003-2004	Migrant
- , LX	Great Lakes	2003-2004	Wintering
- , LX	Great Lakes	2003-2004	Migrant
- , GX	Great Lakes	2003-2004	Migrant
GX, -	Great Lakes	2003-2004	Migrant
bO, LX	Great Lakes	2003-2004	Migrant
LX, O	Great Lakes	2003-2004	Migrant
- , Y/OX	Great Lakes	2003-2004	Migrant
- , gX	Great Lakes	2003-2004	Migrant
Y/OX, OR	Great Lakes	2003-2004	Migrant
BY, O	Great Lakes	2003-2004	Migrant
OY, OX	Great Lakes	2003-2004	Migrant
bX, -	Great Lakes	2003-2004	Migrant
BX, -	Great Lakes	2003-2004	Migrant
bX, OB	Great Lakes	2003-2004	Migrant
b, OR	Great Lakes	2003-2004	Migrant
- , L/OX	Great Lakes	2003-2004	Migrant
-, O/RX	Great Lakes	2004-2005	Wintering
O/LX, BO	Great Lakes	2004-2005	Wintering
R/OX, OG	Great Lakes	2004-2005	Wintering

[a] read left leg to right leg, separated by comma. Letters indicate color bands (L = black, X = metal, O = orange), lower case means light colored (b = light blue, but m = metal above tarsus), colored flag represented by Fw (white flag). Split band indicated by /
[b] migrant (July to October and March to May), wintering (November through February)

APPENDIX A continued

Band Combination	Breeding Population	Study years present on LSSI	Migrant/Wintering
- , Y/OX	Great Lakes	2004-2005	Wintering
- , B/OX	Great Lakes	2004-2005	Wintering
- , g/O/g	Great Lakes	2004-2005	Wintering
- , BX	Great Lakes	2004-2005	Wintering
- , BX	Great Lakes	2004-2005	Migrant
- , BX	Great Lakes	2004-2005	Migrant
- , LX	Great Lakes	2004-2005	Wintering
- , LX	Great Lakes	2004-2005	Migrant
- , LX	Great Lakes	2004-2005	Migrant
bO, GX	Great Lakes	2004-2005	Migrant
- , R/O	Great Lakes	2004-2005	Migrant
B, OR	Great Lakes	2004-2005	Migrant
- , YX	Great Lakes	2004-2005	Migrant
- , gX	Great Lakes	2004-2005	Migrant
- , bX	Great Lakes	2004-2005	Migrant
bX, -	Great Lakes	2004-2005	Migrant
bO, OX	Great Lakes	2004-2005	Migrant
- , b/O	Great Lakes	2004-2005	Migrant
- , b/O	Great Lakes	2004-2005	Migrant
b/O/bX, -	Great Lakes	2004-2005	Migrant
- , O/Y	Great Lakes	2004-2005	Migrant
- , Y/O	Great Lakes	2004-2005	Migrant
- , O/BX	Great Lakes	2004-2005	Migrant
LX, BO	Great Lakes	2004-2005	Migrant
OL, bX	Great Lakes	2004-2005	Migrant
LY, OX	Great Lakes	2004-2005	Migrant
- , g	Great Lakes	2004-2005	Migrant
- , OX	Great Lakes	2004-2005	Migrant
RX, -	Great Lakes	2004-2005	Migrant
YX, -	Great Lakes	2004-2005	Migrant
mGG, FwO	Great Plains	2003-2004	Wintering
mg, FwOR	Great Plains	2003-2004, 2004-2005	Wintering
mB, FwBG	Great Plains	2003-2004, 2004-2005	Wintering
mRg, FwO	Great Plains	2003-2004, 2004-2005	Migrant
mOB, FwY	Great Plains	2003-2004, 2004-2005	Migrant
mB, FwGG	Great Plains	2003-2004	Migrant
X, O	Great Plains	2003-2004	Migrant
W, -, - , X	Great Plains	2003-2004	Migrant
mRgray, W, -	Great Plains	2004-2005	Migrant
mO, W, gray	Great Plains	2004-2005	Migrant
X-RL (“A/B”)	Atlantic Coast	2003-2004	Wintering

APPENDIX A continued

Band Combination	Breeding Population	Study years present on LSSI	Migrant/Wintering
- , X	Atlantic Coast	2003-2004	Wintering
- , X	Atlantic Coast	2003-2004	Migrant
X , -	Atlantic Coast	2003-2004	Wintering
X , -	Atlantic Coast	2003-2004	Migrant
X , -	Atlantic Coast	2003-2004	Migrant
Rgray, X	Atlantic Coast	2003-2004	Migrant
X, bGray	Atlantic Coast	2003-2004	Migrant
X , X	Atlantic Coast	2003-2004	Migrant
RG,X	Atlantic Coast	2003-2004	Migrant
bGray, X	Atlantic Coast	2003-2004	Migrant
m, -, b, -	Atlantic Coast	2003-2004	Migrant
- , X	Atlantic Coast	2004-2005	Wintering
- , X	Atlantic Coast	2004-2005	Wintering
- , X	Atlantic Coast	2004-2005	Migrant
X , -	Atlantic Coast	2004-2005	Wintering
X , -	Atlantic Coast	2004-2005	Wintering
X , -	Atlantic Coast	2004-2005	Migrant
bGray, -	Atlantic Coast	2004-2005	Migrant
X, Gray	Atlantic Coast	2004-2005	Migrant
bGray, X	Atlantic Coast	2004-2005	Migrant
B, - , Y, -	Atlantic Coast	2004-2005	Migrant
m, - , L/b, -	Atlantic Coast	2004-2005	Migrant
O, X	Unknown	2004-2005	Migrant
F?O, m?BB?	Unknown	2004-2005	Migrant
- , - , m, -	Unknown	2004-2005	Migrant
mO,?X?	Unknown	2004-2005	Migrant

APPENDIX B

NUMBER OF PIPING PLOVERS, BANDED PIPING PLOVERS, AND GREAT LAKES PIPING PLOVERS ON LITTLE ST. SIMONS ISLAND BY MONTH

Month/Year	Mean ± SE		
	Piping Plovers	Banded Piping Plovers	Great Lakes Piping Plovers
Jul-03	21.25 ± 2.14	6.75 ± 2.46	4.00 ± 1.83
Aug-03	54.50 ± 5.18	11.50 ± 1.56	6.75 ± 1.89
Sep-03	75.00 ± 6.98	14.83 ± 1.42	9.00 ± 1.37
Oct-03	54.50 ± 3.59	15.33 ± 1.28	9.50 ± 0.85
Nov-03	46.80 ± 4.27	12.20 ± 1.07	8.40 ± 0.75
Dec-03	47.67 ± 2.47	12.00 ± 1.07	8.33 ± 0.88
Jan-04	43.80 ± 3.89	10.60 ± 1.75	7.20 ± 1.11
Feb-04	48.60 ± 5.39	12.80 ± 1.56	9.00 ± 0.84
Mar-04	64.88 ± 3.88	14.25 ± 1.08	9.50 ± 0.68
Apr-04	52.71 ± 3.36	12.00 ± 1.23	8.29 ± 0.97
May-04	4.33 ± 1.17	0.20 ± 0.18	0.20 ± 0.18
Jul-04	50.25 ± 9.32	11.38 ± 1.40	10.38 ± 1.05
Aug-04	101.00 ± 4.15	18.29 ± 0.87	12.71 ± 0.89
Sep-04	99.67 ± 5.00	20.00 ± 1.07	12.67 ± 1.02
Oct-04	79.29 ± 9.20	20.00 ± 1.13	14.43 ± 0.97
Nov-04	53.83 ± 4.27	14.50 ± 1.23	11.50 ± 0.96
Dec-04	40.75 ± 4.07	11.50 ± 1.56	8.50 ± 0.87
Jan-05	42.00 ± 3.39	11.33 ± 0.84	8.20 ± 0.53
Feb-05	22.80 ± 0.86	8.40 ± 0.75	6.80 ± 0.86
Mar-05	30.83 ± 4.43	10.50 ± 0.62	8.00 ± 0.45
Apr-05	37.86 ± 4.23	11.00 ± 1.07	9.57 ± 0.75
May-05	5.67 ± 2.64	1.33 ± 0.88	1.33 ± 0.88

APPENDIX C

NUMBER OF PIPING PLOVERS (MEAN ± SE) AT SANCHO PANZA BEACH BY MONTH

Month and Year	Piping Plovers at Low Tide	Piping Plovers at High Tide	Great Lakes Piping Plovers at Low Tide
Jul-03	N/A	0	N/A
Aug-03	18.25 ± 3.77	8.50 ± 1.50	3.67 ± 2.19
Sep-03	25.33 ± 4.91	11.00 ± 2.85	5.33 ± 1.20
Oct-03	26.60 ± 2.87	5	6.60 ± 0.51
Nov-03	17.25 ± 1.80	3	5.25 ± 0.48
Dec-03	6.50 ± 1.89	10.00 ± 0.00	2.25 ± 0.75
Jan-04	11.00 ± 2.65	4.50 ± 3.50	2.67 ± 0.88
Feb-04	12.75 ± 3.90	14.00 ± 1.00	3.00 ± 1.08
Mar-04	27.60 ± 4.01	16.25 ± 4.61	6.20 ± 1.80
Apr-04	17.50 ± 3.23	0	4.00 ± 0.26
May-04	0.25 ± 0.25	0	0.00 ± 0.00
Jul-04	37.40 ± 4.03	5.00 ± 4.00	8.00 ± 0.45
Aug-04	46.33 ± 1.86	15.00 ± 8.00	7.33 ± 1.20
Sep-04	51.33 ± 0.33	22.30 ± 4.65	6.33 ± 1.86
Oct-04	27.17 ± 3.24	26	6.17 ± 0.79
Nov-04	26.20 ± 1.56	N/A	7.20 ± 0.86
Dec-04	19.33 ± 0.67	16	4.67 ± 0.67
Jan-05	18.67 ± 3.67	1	4.67 ± 1.02
Feb-05	18.60 ± 1.32	N/A	5.60 ± 0.51
Mar-05	20.80 ± 2.25	20.33 ± 3.33	6.80 ± 0.80
Apr-05	34.00 ± 3.94	16.50 ± 3.12	9.17 ± 0.75
May-05	3.00 ± 2.01	2	1.00 ± 0.78

APPENDIX D

NUMBER OF PIPING PLOVERS (MEAN ± SE) AT BASS CREEK BY MONTH

Month and Year	Piping Plovers at Low Tide	Piping Plovers at High Tide	Great Lakes Piping Plovers at High Tide
Jul-03	N/A	N/A	N/A
Aug-03	36	16.00 ± 1.41	3
Sep-03	6.33 ± 1.20	54.67 ± 15.51	8.67 ± 0.82
Oct-03	8.40 ± 0.24	35	9
Nov-03	8.50 ± 1.85	20	6
Dec-03	19.20 ± 0.73	18	3
Jan-04	12.33 ± 1.76	17.50 ± 2.50	4.00 ± 0.00
Feb-04	13.00 ± 0.58	17.00 ± 2.52	4.00 ± 1.00
Mar-04	3.83 ± 2.75	24.00 ± 1.15	4.00 ± 1.73
Apr-04	12.83 ± 2.44	20.33 ± 4.18	2.33 ± 0.88
May-04	2.00 ± 1.00	0	0.00 ± 0.00
Jul-04	3.75 ± 1.65	9.67 ± 5.18	3.00 ± 0.00
Aug-04	7.00 ± 2.00	64.80 ± 4.87	7.80 ± 1.43
Sep-04	10.25 ± 4.82	23.67 ± 3.93	3.33 ± 1.76
Oct-04	15.00 ± 7.11	26	7
Nov-04	5.20 ± 0.97	21	6
Dec-04	4.67 ± 2.33	11	2
Jan-05	14.80 ± 6.35	23	4
Feb-05	4.00 ± 2.35	N/A	N/A
Mar-05	1.20 ± 1.20	7.50 ± 4.50	2.50 ± 1.50
Apr-05	0.00 ± 0.00	8.50 ± 1.50	3.00 ± 0.00
May-05	0.20 ± 0.20	2	0

APPENDIX E

NUMBER OF PIPING PLOVERS (MEAN ± SE) AT MIDDLE BAR BY MONTH

Month and Year	Piping Plovers at Low Tide	Piping Plovers at High Tide	Great Lakes Piping Plovers at Low Tide
Jul-03	22.50 ± 4.50	20.00 ± 2.00	4.00 ± 4.00
Aug-03	27.33 ± 2.96	29.25 ± 1.49	3.00 ± 1.00
Sep-03	21.00 ± 6.00	24.17 ± 8.42	0.50 ± 0.50
Oct-03	18.50 ± 3.43	12.50 ± 0.50	0.75 ± 0.48
Nov-03	17.50 ± 1.44	19	1.75 ± 0.25
Dec-03	20.20 ± 1.02	23	2.00 ± 0.00
Jan-04	20.67 ± 0.88	13.00 ± 9.00	2.33 ± 0.33
Feb-04	16.75 ± 5.62	18.00 ± 0.00	1.67 ± 0.88
Mar-04	25.33 ± 4.37	19.50 ± 3.97	1.33 ± 0.67
Apr-04	15.33 ± 2.29	20.00 ± 3.00	1.50 ± 0.24
May-04	1.50 ± 1.50	0.00 ± 0.00	0.00 ± 0.00
Jul-04	18.50 ± 3.50	20.05 ± 3.07	3.00 ± 1.00
Aug-04	20.33 ± 0.88	39.25 ± 5.98	2.00 ± 0.58
Sep-04	20.50 ± 0.87	23.67 ± 4.81	1.50 ± 0.65
Oct-04	16.80 ± 2.25	24.00 ± 5.00	1.80 ± 0.58
Nov-04	14.33 ± 1.76	15.00 ± 4.00	1.33 ± 0.33
Dec-04	3.67 ± 0.33	13	0.67 ± 0.33
Jan-05	4.80 ± 3.63	29	0.60 ± 0.40
Feb-05	0.25 ± 0.25	N/A	0.25 ± 0.25
Mar-05	3.80 ± 1.63	2.25 ± 0.48	0.00 ± 0.00
Apr-05	1.50 ± 0.72	2.75 ± 1.32	0.17 ± 0.17
May-05	0.60 ± 0.40	0	0.20 ± 0.20

APPENDIX F

NUMBER OF PIPING PLOVERS (MEAN ± SE) AT RAINBOW BEACH BY MONTH

Month and Year	Piping Plovers at Low Tide	Piping Plovers at High Tide	Great Lakes Piping Plovers at Low Tide
Jul-03	N/A	N/A	N/A
Aug-03	N/A	N/A	N/A
Sep-03	N/A	N/A	N/A
Oct-03	2.67 ± 0.33	N/A	0.00 ± 0.00
Nov-03	6	N/A	1
Dec-03	0	N/A	0
Jan-04	5	13	0
Feb-04	1	1	0
Mar-04	9.67 ± 2.40	13.00 ± 2.31	0.50 ± 0.50
Apr-04	6.00 ± 1.00	7.67 ± 1.33	2
May-04	1.75 ± 0.48	0.00 ± 0.00	0.00 ± 0.00
Jul-04	2.50 ± 0.50	2	1.50 ± 0.50
Aug-04	10.67 ± 2.91	4.00 ± 2.00	1.50 ± 0.50
Sep-04	8.00 ± 0.00	7.50 ± 0.50	1.00 ± 0.00
Oct-04	7.00 ± 1.00	5.33 ± 1.76	0.50 ± 0.50
Nov-04	8.67 ± 0.67	7	1.00 ± 0.00
Dec-04	2	3	0
Jan-05	1.00 ± 1.00	1.50 ± 1.50	0.00 ± 0.00
Feb-05	2.00 ± 1.00	N/A	0.00 ± 0.00
Mar-05	6.00 ± 4.16	5.33 ± 1.86	0.00 ± 0.00
Apr-05	5.00 ± 0.82	3	0.67 ± 0.21
May-05	2.20 ± 1.02	N/A	0.40 ± 0.25